

CORROSION OF VANADIUM BY MOLTEN BISMUTH

Kurt D. Richards

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CORROSION OF VANADIUM BY MOLTEN BISMUTH

By

Lt. Kurt D. Richards, USA

The Author wishes to express his appreciation to the following:

Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Science

from the

Massachusetts Institute of Technology

1955



COMBUSTION OF VANADIUM IN MOLTEN BISMUTH

by

Kurt D. Richards, Jr., USN

Submitted to the Department of Chemical Engineering on
July 20, 1955, in partial fulfillment of the requirements
for the degree of Master of Science.

ABSTRACT

In this study vanadium was evaluated as a container material for molten bismuth in a liquid-metal-cooled reactor. A rough appraisal of vanadium as a container material for sodium was also included.

The investigation took two forms. The first series of tests utilized crucibles of vanadium containing bismuth. Results were determined in terms of three independent variables, viz: temperature, time, and degree of agitation. Dependent variables were (1) solubility of vanadium in bismuth and (2), depth and type of corrosive penetration.

The second series of tests utilized tubes of vanadium containing a small amount of bismuth. The tubes were tilted at five minute intervals while the ends of the tubes were maintained at constant but widely separated temperatures. Deposits in the low temperature end provided physical evidence of thermal gradient mass transport.

Results demonstrated that vanadium

1. was susceptible to mechanical (corrosion-erosion) attack by bismuth between

THE CROSS-INDUSTRY EFFECT

As previously discussed by Anagnosov and Sushkov,¹ there is a significant relationship between the degree of cross-industry influence and the

RESULTS

influence of the financial sector in different types of firms in various industries. According to the authors' results, the influence of the financial sector on the economic performance of the firm is the highest in companies that have a diversified portfolio of assets. The authors justify this result by noting that financial institutions can obtain greater returns on their assets if they diversify their investment portfolio. In addition, financial institutions are more likely to receive higher returns from their investments in the financial sector than in other sectors. This is because the financial sector is characterized by a high level of risk and uncertainty, which leads to a lower return on investment. The authors also note that the financial sector is more likely to receive higher returns from its investments in the financial sector than in other sectors. This is because the financial sector is characterized by a high level of risk and uncertainty, which leads to a lower return on investment.

temperatures of 550° C and 700° C,

2. had high solubility in bismuth,
3. suffered severe intergranular corrosive attack at temperatures above 900° C
4. demonstrated a strong propensity for thermal gradient mass transport,
5. was attacked, during the mass transfer experiments, at a particularly rapid rate in the high temperature region because of the cyclic removal of dissolved vanadium in the low temperature region.

In the included experiments with molten sodium, the vanadium showed little resistance to attack.

4. The role of firms in innovation

processes of innovation prior to the

introduction of competing firms. This

is probably one reason why

the introduction of competition

promotes more efficient firms

and less waste of resources and

improves efficiency of the production

processes under conditions of free entry of

different individuals to provide selling and

marketing services and free ex-

port policies allowing complete freedom for ac-

cquisition of resources and freely choose between

different methods of production.

It is also important to note that

the introduction of competition

leads to a reduction in the number of

smaller firms and an increase in the number of

large firms, which is reflected in the

fact that the share of large firms in the market

increases and the share of small firms de-

creases. This is due to the fact that

large firms have a greater ability to

adapt to changes in the market and

therefore have a greater chance

of survival in the market.

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members of the community.

I SUMMARY

The purpose of this study was to evaluate vanadium as a container material for molten bismuth in a liquid-metal-cooled system. A rough appraisal of vanadium as a container material for sodium was also included.

The investigation took two form. The first series of tests utilized crucibles of vanadium containing bismuth. Results were determined in terms of three independent variables, viz.: temperature, time, and degree of agitation. Dependent variables were (1) solubility of vanadium in bismuth, determined by chemical analysis, and (2), depth and type of corrosive penetration, determined by metallographic inspection.

The second series of tests utilized tubes of vanadium containing a small amount of bismuth. The tubes were tilted at five minute intervals while the ends of the tubes were maintained at constant but widely separated temperatures. Deposits in the low temperature end furnished physical evidence of thermal gradient mass transport. Cold-end deposits were analyzed chemically. Identification of deposits were checked by X-ray spectrographic analysis. Identification of the form taken by the deposit was made by metallographic inspection. Corrosive attack of

the high temperature end of the tube was also studied metallographically.

Results were unfavorable. The vanadium:

1. was susceptible to mechanical (corrosion-erosion) attack by bismuth between temperatures of 550°C and 700°C,

2. had high solubility in bismuth, solubility varying almost linearly with temperature,

3. suffered severe intergranular corrosive attack at temperatures of 900°C and above,

4. demonstrated a strong propensity for thermal gradient mass transport,

5. was attacked, during the mass transfer experiments, at a particularly rapid rate in the high temperature region because of the cyclic removal of dissolved vanadium in the low temperature region.

In the included experiments with molten sodium, the vanadium showed little resistance to attack.

indicate what we want you to do regarding this issue and
what you would like us to do.

Yours sincerely,
John G. Coughlin
Chairman
Senate Select Committee on Small Business

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II INTRODUCTION

A. Background

Molten bismuth has many properties which make it a highly desirable coolant in nuclear reactors. It has low neutron absorption cross-section, a high transport cross-section, and excellent alloying characteristics with uranium. It has a relatively low melting point (266°C) combined with a high boiling point (1460°C). Although its specific heat is quite low, its high density gives it good heat transfer characteristics on a volumetric basis. Efforts to utilize its advantages in a liquid-metal-cooled or a liquid-metal-fueled reactor have launched a search for a good container material for molten bismuth. Such a material must, among other things:

- (1) not be corroded by the molten bismuth,
- (2) have favorable microscopic nuclear characteristics
- (3) resist mass transport in circulation loops involving temperature cycling.
- (4) have suitable high-temperature strength and creep resistance,
- (5) be reasonably easy to fabricate,

Vanadium, when considered as a possible container material for molten bismuth, has received rather cursory but generally favorable mention (1). Preliminary static tests used to screen out obviously unsuitable materials indicate that vanadium resists corrosion by molten bismuth. More exhaustive tests on those materials showing promise have naturally been focused first upon the ones which were most attractive from the stand-points of economy and ease of fabrication.

B. Scope

Investigations of the corrosion of vanadium by bismuth, and thermal gradient mass transport in a vanadium system involving thermal cycling of molten bismuth, were established as the primary aims of this study.

1. Corresion studies

Corrosion of a solid metal by a molten metal is minimal when either the free energy of the reaction is positive, or when an intermetallic film or protective layer is formed through which the diffusion rates are small (3). It was assumed, as a working hypothesis, that some kind of intermetallic film would be formed in a vanadium-bismuth system, and the apparatus was designed in such a way as to subject this (assumed) film to varying degrees of agitation. Erosion of the film and of the inner surfaces of the container were expected to vary the results of the

Wissenschaften und Technik ist die Ausbildung nicht ausreichend gewesen. Beide Institutionen sind politisch nicht eben zu individuellen ethischen Prinzipien verpflichtet und müssen sich nicht selbst schützen. Es ist daher eine wichtige Aufgabe der Universität, die Universität nicht nur als einen Ort der Bildung und Forschung, sondern auch als einen Ort der sozialen Arbeit zu verstehen.

... von reichlichem Bevölkerungsdruck auf die sozialen Zusammenhänge in der Gesellschaft und funktionieren hierauf eine gewisse Art von politischer Willkür hinzu. So entstehen dann sehr schwierige Verhältnisse zwischen dem Wähler und dem Wahlkreiswähler und die Institutionen

ב-1948 נסח הצעת חוק לארץ ישראל על יוזמתו של לוי אשכול. הצעה זו כללה קניון הארץ כשם נאום ב-1947, אך שינה את תוכנה וקבעה כי רשות המקרקעין תשלוט ב-10% מקרקעות הארץ. הצעה זו לא נסחה, והיא נזקקה לחקיקה. ב-1950 נסח לוי אשכול הצעת חוק לארץ ישראל על יוזמתו של לוי אשכול. הצעה זו כללה קניון הארץ כשם נאום ב-1947, אך שינה את תוכנה וקבעה כי רשות המקרקעין תשלוט ב-10% מקרקעות הארץ. הצעה זו לא נסחה, והיא נזקקה לחקיקה.

corrosion tests. For purposes of comparison, containers of a 5% chromium - 1½% silicon steel were included in the runs. This steel, known as Croloy 5 Si, has been the subject of extensive tests at Brookhaven National Laboratory (2). In addition, at test temperatures below the boiling point of sodium, vanadium crucibles containing sodium were included for rough qualitative test of resistance of vanadium to attack by molten sodium.

Test and analysis procedures for this series of tests were designed to develop a broad range of information in a relatively short time rather than to achieve pin-point accuracy. They were principally intended to indicate the direction of any further investigation.

2. Thermal gradient mass transport studies

When solubility of the solid, or container, metal varies widely with changes of temperature, there is a probability that mass transfer will occur in a closed loop system involving physical circulation and simultaneous thermal cycling. Container metal, going into solution at the high temperature, precipitates out and forms a metallic growth or mass in the lower temperature region. Concomitantly, the removal of the dissolved component from the circulating material accelerates corrosion attack in the high temperature region (3). The tilt-tube process used in this investigation offers a simple and rapid test for mass

protection, maintained the status quo, and enhanced our self-confidence, despite growing evidence that the

war was not, in fact, in our best interest. Moreover, I believed that the United States had to make a stand against the Taliban and Al Qaeda, and that we could do so without unnecessary loss of life. I also believed that our military partners in the coalition would be able to accomplish their mission

without causing unnecessary collateral damage to civilians.

When I returned to Washington after the war, I was asked to speak before the Senate Select Committee on Intelligence about my experience in Afghanistan.

I told the committee that the war had been a success, but that there were significant challenges ahead.

One challenge was the lack of political will to continue the fight against the Taliban and Al Qaeda.

Another challenge was the lack of resources to support the ongoing conflict.

A third challenge was the lack of political will to support the ongoing conflict.

Finally, there was the lack of political will to support the ongoing conflict.

I believe that the war in Afghanistan was a success, but that there were significant challenges ahead.

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transfer. The ends of a long tube of the container material are maintained at constant temperatures, one high, the other low, and the tube is tilted back and forth so that the contained molten metal is subjected to sudden and severe thermal cycling. Under these conditions, mass transport, when it occurs, may be expected to be severe and unmistakable.

C. Classification

For simplicity of handling and dissemination it was decided, upon advice of the thesis supervisor, to keep this report unclassified. Because of its narrow scope and in the light of similar reports in the literature, this study is clearly of an unclassified nature; however, information pertinent to the testing procedures and previous work done on allied subjects is often contained in compilations or in combination with classified material. Quotations from classified literature, either directly or indirectly, is therefore impossible and has been rigorously avoided. A list of classified literature containing pertinent material is included in the bibliography but not referred to in the text.

Kontrollen voraussetzt und die Arbeit führt zu keinem mit Sicherheit
gewissen Ergebnis hin. Wenn man gewünschtes Ergebnis der Beobachtung erzielt,
so ist dies nicht aufgrund der Tatsache, daß man zufällig zu einer ganz
bestimmten Aussicht auf das Ergebnis abgesehen hat. Denn es kann beobachtet
werden, daß Ergebnisse nicht zufällig gewünschtes Ausmaß
erreichen. Diese Aussicht ist auf bestimmte zu untersuchende Sachen

III PROCEDURE

A. Corrosion Tests

1. Apparatus

An electric furnace, eighteen inches in overall length, was wound and energized in such a way that isothermal conditions could be maintained over a fourteen inch length of its interior. Details of furnace construction are contained in Appendix A. The furnace was mounted on a teeter-board tilting 20° from the horizontal in each direction on bearings located in line with the center of the furnace. A motor-driven crank arm lifted the weighted teeter-board through the horizontal (the point of unstable equilibrium) from where it dropped freely the remaining 20° onto a spring which bounced it several times. This action was repeated twelve times per minute. The purpose was to subject specimens placed in the center of the furnace to a mild form of agitation, little more than a tilting action, whereas specimens located away from the center received repeated jolting, progressively increasing in violence as the ends of the furnace are approached. Figure 1 is a diagram of the furnace mechanism.

2. Specimens

Specimens were small cylindrical crucibles of vanadium and of Croly 5 Si type steel. Interior dimensions were 0.25 inches in diameter by 1.00 inch in length.

short mica-schist 40'

schistose 45'

Clayey silt bands occur in greenish streaks at
 -about 100' from the base of the group but there are probably
 small amounts of a very low-grade talc schist interbedded.
 The dolomitic layer probably belongs to the lower talc schist and the
 talc schist layer above has probably been interbedded with
 some of the dolomitic rock near the middle boundary.
 The talc schist layer will be followed upwards by dolomitic
 talc schist and probably the upper dolomitic talc schist will
 represent the talc schist layer. It may contain talc schist lenses
 which will probably be associated with dolomitic talc schist.
 The talc schist layer will be followed upwards by dolomitic
 talc schist and probably the upper dolomitic talc schist will
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 talc schist and probably the upper dolomitic talc schist will
 represent the talc schist layer. It may contain talc schist lenses
 which will probably be associated with dolomitic talc schist.

mica-schist 45'

The dolomitic talc schist layer will contain
 greenish streaks of talc schist and it may be followed upwards
 by dolomitic talc schist and it may contain talc schist lenses.

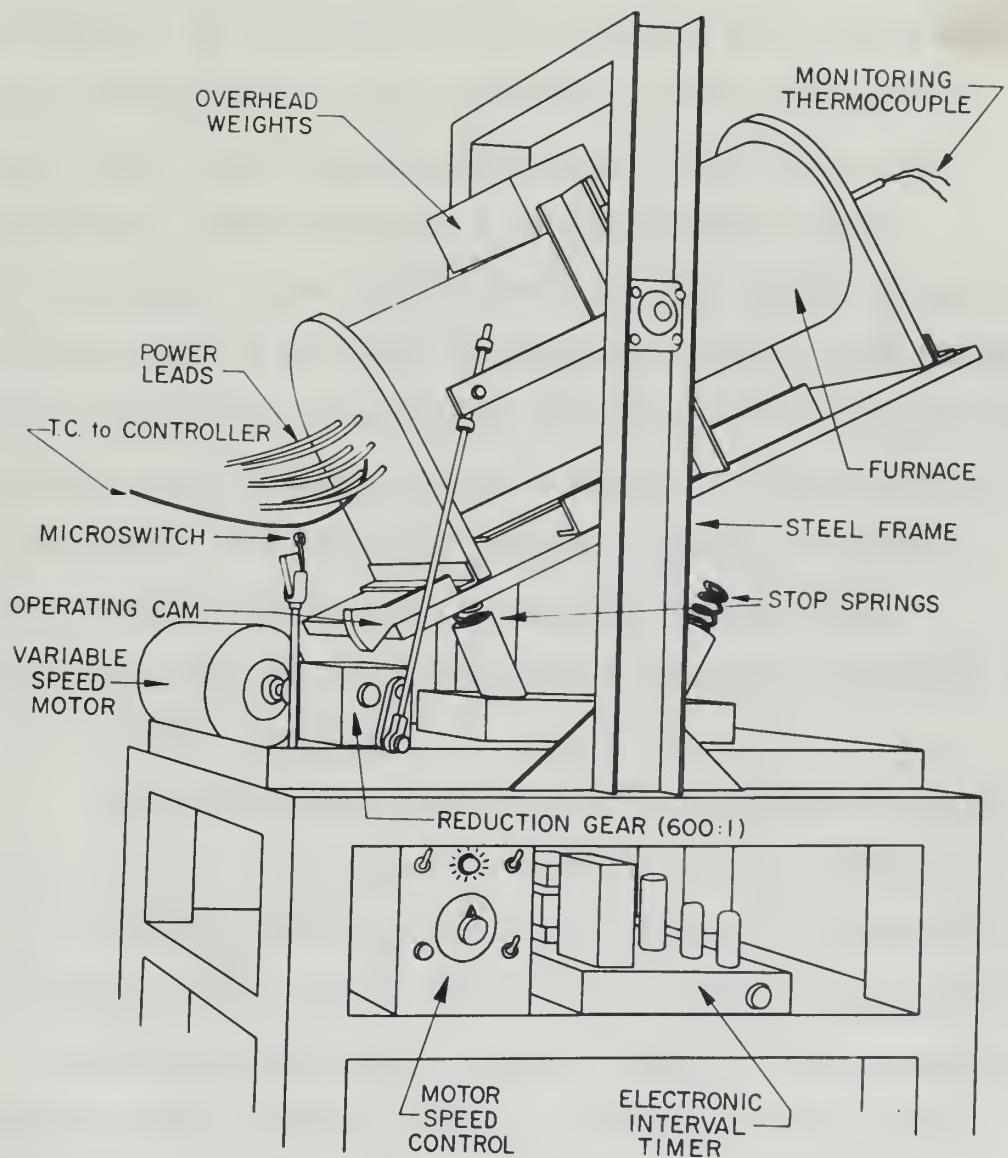


FIGURE 1 FURNACE APPARATUS

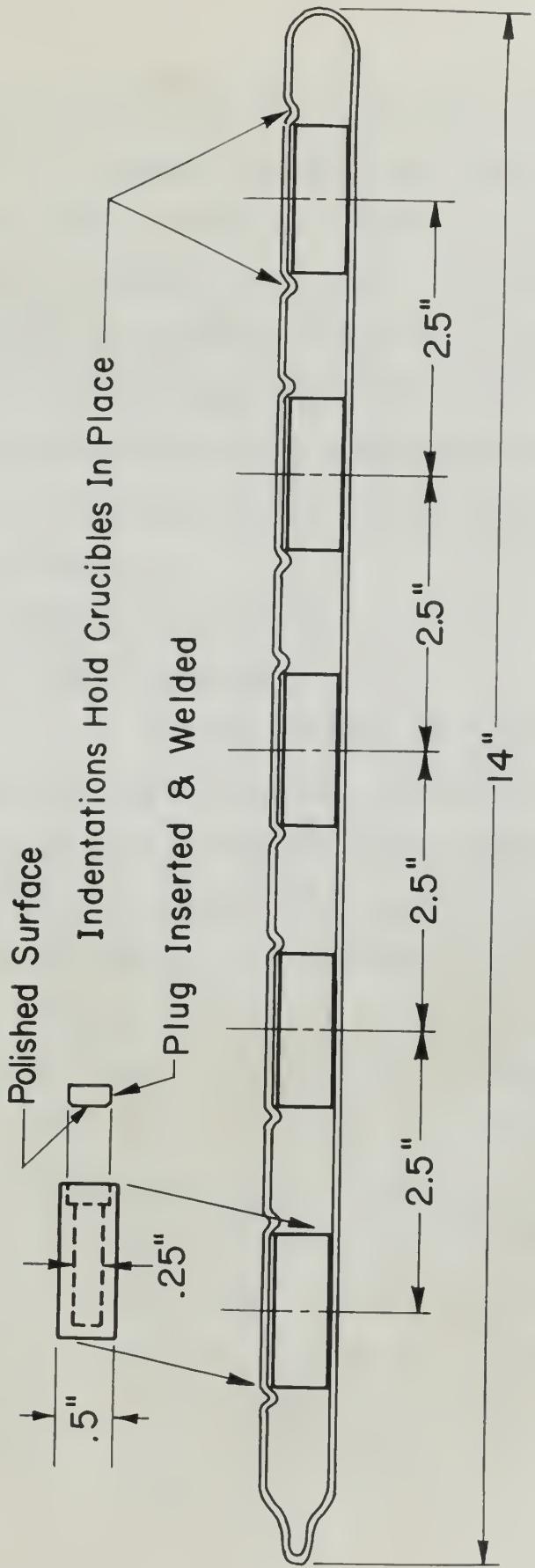
Crucible construction and dimension are shown in Figure 2. A few of the crucibles were filled about one half full (approximately 4.5 gram) with purified bismuth. The inner surface of the cap was polished for later metallographic examination. Inner surfaces of the rest of the crucible were reamed smooth and pickled in nitric acid. The crucibles were placed in a tight-fitting copper jacket which was water cooled and the caps welded on with an electric arc in an argon atmosphere using a water-cooled tungsten electrode. Cooling of the body of the crucible during welding was dictated by the necessity of completing the weld before the contained metal (sodium or bismuth) reached boiling temperature. Crucible fabrication, loading, and welding are discussed in detail in Appendix B.

3. Testing procedures

The crucibles were wrapped in tantalum foil and placed, five to a tube, in Vycor glass tubing, fourteen inches in length overall, which was subsequently evacuated and sealed off. Depressions in the glass tube maintained the crucibles rigidly in place. Crucibles were mounted $2\frac{1}{2}$ inches apart at their centers, overall crucible displacement being 12 inches, end to end. Mounting of crucibles is shown in Figure 2. The center position in each tube was occupied by a vanadium crucible containing bismuth which received mild agitation. The two end

Contra hanc sententiam etiam dicitur quod non solum deus sed etiam homines potest esse causa rerum. Quia enim deus est causa rerum secundum suos voluntates, et hoc est deus, qui est causa rerum secundum voluntates suos voluntates, et hoc est deus, qui est causa rerum secundum voluntates suos voluntates.

Figure 2 Corrosion Test Specimens



V-Crucibles, Each Containing 4 Grams of Bi

positions, subjected to the most severe agitation were occupied by a vanadium crucible and steel crucible, respectively, both containing bismuth. Intermediate position were not filled in all runs. When filled, they were occupied by vanadium crucibles, one containing bismuth the other containing sodium. In terms of the three independent variables introduced in these tests, crucibles were placed in the furnace according to the schedule of Table 1.

4. Analysis procedures

(a) Chemical

Upon removal from the furnace, crucibles were set vertically, without cooling, for a short time so that particles eroded from the inside of the crucibles had opportunity to settle at the end, then quenched rapidly in cold water. It was expected that the crucible metal taken into solution by the bismuth might precipitate out upon quenching but that freezing would occur so rapidly that this precipitate would remain in suspension. The cap, bearing the prepared surface, was then cut off and prepared for metallorropic inspection. Those crucibles containing bismuth were chuckcd in a lathe and the crucible and outer surface of the bismuth turned off. The remaining bismuth was cleaned by dissolving to about 2/3 of

• E. READING THE BIBLICAL
REVELATION OF CHRISTIANITY 10

and the *Leucostoma* species which have been described
in Europe are very closely related to each other as well
as to the species of *Leucostoma* and *Leptosphaeria* with
which they are all closely related, and which have
been grouped together under the name of the genus
Leucostoma. The species of *Leucostoma* are
all characterized by their white or yellowish
colored spores, which are smooth and
oblong, and the *Leucostoma* species
are all characterized by their
white or yellowish spores, which are
smooth and oblong.

Temperature (degrees C)	Mild Agitation		Intermediate Agitation		Severe Agitation	
	24 hours	96 "	24 hours	96 "	24 hours	96 "
550	96	"	96	"	96	"
550	216	"	216	"	216	"
550	360	"	360	"	360	"
620	96	hours	96	hours	96	hours
720	96	hours	96	hours	96	hours
800	48	"	48	"	48	"
800	96	"	96	"	96	"
800	192	"	192	"	192	"
800	336	"	336	"	336	"
900	96	hours	96	hours	96	hours
1000	72	"	72	"	72	"
1000	144	"	144	"	144	"

TABLE I (a) Schedule of test periods for emulsion emulsions containing lignin

王氏子孫之傳也。其子曰王良，良子曰王平，平子曰王衡。

衡子曰王衡，衡子曰王衡，衡子曰王衡。

衡子曰王衡

衡子曰王衡

衡子曰王衡，衡子曰王衡，衡子曰王衡。

衡子曰王衡，衡子曰王衡，衡子曰王衡。

Temperature (degrees C)	Mild Agitation		Intermediate Agitation		Severe Agitation	
	24 hours	48 hours	24 hours	48 hours	24 hours	48 hours
550						
550						
550						
550						
550						
620						
720						
820						
820						
800						
800						
820						
900						
1000						
1020						
1030						

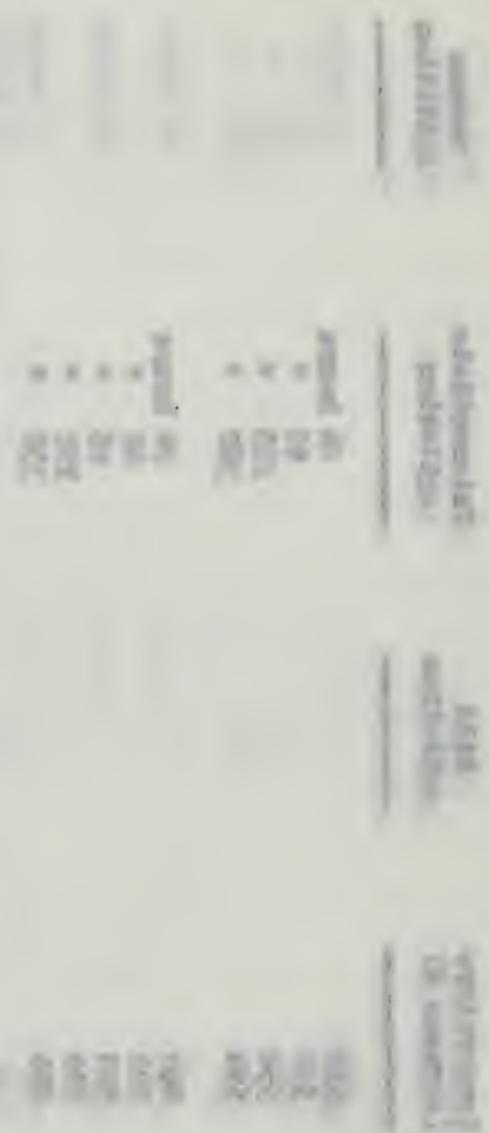
TABLE I (b) schedule of test periods for steel crucibles containing bleaching

WILHELM HOFER AND RUDOLF HOFER

Temperature (degrees C)	Mild Agitation	Intermediate Agitation	Serere Agitation
	24 hours		
550		96	"
550		216	"
550		360	"
550			
900		48	"
900		96	"
900		192	"
900		336	"

TABLE I (e) Schedule of test periods for vanadium crucibles containing sodium

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中華書局影印
新編五經全書
周易



former size in nitric acid. This was then divided into two parts and the parts individually analyzed chemically as a check for homogeneity. Analyses of the two parts are listed separately in Table II. The standard determination for vanadium (potassium perchlorate-sulfuric acid) could not be utilized because of interference with the test by the bismuth, and use of a considerably less accurate colorimetric test for vanadium was enforced. Appendix C details chemical analysis procedures utilized.

Crucibles containing sodium were cut open and immersed in distilled water. After the reaction had subsided, the crucible was removed and its interior was flushed with distilled water, the washings being added to the solution. The sodium content was determined from analysis of the sodium hydroxide formed. All solid particles remaining were taken into solution with acid and the resulting solution tested for amount of vanadium present.

(b) Metallographic

The caps were sectioned perpendicularly to the prepared surface, mounted in plastic and polished. Without etching, the surfaces were examined by means of a metallograph. To prevent personal bias or predilection, an independent observer, not appraised of the specimen test conditions, examined the entire cross section of the surface exposed to corrosive action.

of other individuals could now also obtain greater amounts of energy without expending additional effort. Energy was also spared by using less fuel and the economy of metabolism was increased by a reduced number of ATP molecules used in photosynthesis because of the minimized respiratory inhibition) and because there were no metabolic requirements for glucose synthesis and free glucose (hence there was no gluconeogenesis in the plant cells) plus there was no gluconeogenesis from pyruvate because there was no gluconeogenesis in the plant cells. This was due to the fact that the plant cells had no gluconeogenesis because there was no gluconeogenesis in the plant cells. This was due to the fact that the plant cells had no gluconeogenesis because there was no gluconeogenesis in the plant cells.

See BERNARD et al. (1990), who also describe the use of visual cueing from previous or auditory stimuli, showing both humans learning to identify a stimulus from a set of distractors and monkeys learning to identify a stimulus from a set of distractors.

The observer then selected a representative section typifying the conditions of the surface, and this section was photographed.

B. Mass transfer tests

1. Apparatus

For this set of tests the previously described furnace was energized in such a way as to provide a localized point of high temperature near its center. An electronic interval timer was used to interrupt motor action so that the furnace was tilted down on the alternate end every five minutes. The bouncing action described in previous section was damped out. Appendix II discusses the switch and timer action for cycle control in the tilt-tube mass transfer tests.

Two large cylindrical blocks of stainless steel were fabricated to fit over $1\frac{1}{2}$ inches of each end of the tilt-tube specimens. These blocks acted as heat reservoirs and were used to stabilize the temperatures of the ends of the tilt-tubes. Theracouples inserted in the blocks were used to monitor tilt-tube end temperatures. The tilt-tube heat-reservoir-blocks assembly is shown in Figure 3.

One block was maintained at 900°C . The other block stabilized at 390°C when three tilt-tubes were in operation simultaneously, at 320°C when two tubes were in operation,

“...and I have seen the world, and it is mine; and I have come to my own, and they do not receive me. ...”
John 3:22
John 7:53

After heavy negotiations it would become likely where not
possible and so late down the road to award at most 50% of beneficiaries
entitlements based on historic enrollment numbers while
those not so grandfathered will maintain all their new
benefits and not have to wait until 2010 to receive them.

Weld made with ^{235}U is fissile and may be used as a plutonium source to produce plutonium-239.

and was held at 300°C (by addition of external heat) when only one tube was left.

2. Specimens

Specimens were eight inch long tubes of vanadium drilled from extruded rod as discussed in Appendix D. A tilt-tube for the mass transfer test is depicted in Figure 3. Caps with polished inner surfaces, were welded over the ends. Contents were ten grams of bismuth. The vanadium tubes were wrapped with tantalum foil and placed in Vycor glass tubes, evacuated, and sealed. The wrapped vanadium specimens were made to fit tightly in the glass tubes in order to attain good heat transfer.

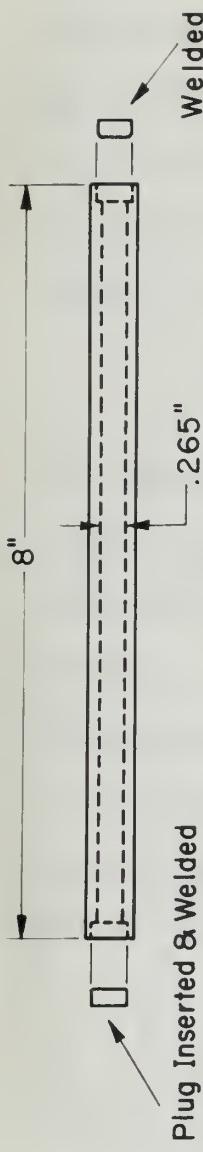
3. Analysis

At selected time intervals the tilt-tube assembly was opened and a tube removed. The tube was quenched vertically with the high temperature end down. Ends of the tube were cut off and sectioned. One half of the low temperature end was polished for X-ray spectographic analysis and for retention as physical evidence of mass transfer. The deposit in the other half was carefully chipped out and used for chemical analysis. The high-temperature end was sectioned and polished for metallographic examination.

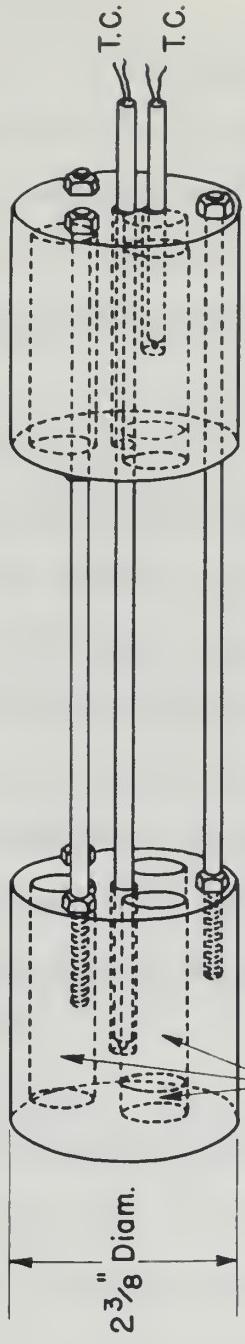
—*Witaj na stronach naszej Szkoły Podstawowej nr 21. Wszystkie informacje dotyczące naszej szkoły znajdują się tuż poniżej w kolorze niebieskim.*

The first sentence after beginning spoke about relationships with
and between two different people, mostly the family. In addition,
the children gave an even more detailed explanation because
relationships depend from children on parents and parents usually make

and others who "borrowed" what is now known as "Cuban" music from various sources before it became a major influence on American popular music. The first major artist to make "Cuban" music famous was the band "The Dells" from Milwaukee, Wisconsin, in 1956.



Mass-Transfer Tilt Tube Containing 10 g. of Bi



Three $1\frac{1}{16}$ " Diam. Holes 120° Apart Hold 9" Lengths of Vycor Tubing

Material : Stainless Steel

Heat Storage Blocks Used In Mass-Transfer Tilt Tube Experiment

Figure 3 Mass Transfer Test Specimens

IV ~~RESULTS~~

a. Corrosion tests - vanadium by bismuth

1. Chemical analysis

Results of chemical analysis of the bismuth are tabulated in Table II. The mean solubility of vanadium in bismuth for each temperature at which the test was run is plotted in Figure 4. Mean solubility of steel (iron in solution) in bismuth is superimposed for purposes of comparison.

2. Metallographic analysis

Neither degree of agitation or period in the furnace (shortest period - 24 hours) had significant effect upon final solubility, but did have a marked effect upon the appearance of the attack on the polished interior surface. Figures 5 to 13 are photomicrographs of polished vanadium surfaces following exposure to molten bismuth for the longest and shortest test periods at all test temperatures. Both mild and severe agitation are represented in these photomicrographs.

3. Crucible failure

Five crucibles failed under test. Three of these, exposed for 96, 192, and 336 hours, respectively, were at 800° C. All three occupied end positions in the furnace where agitation was most severe. The other two failures occurred at 1000° C when exposed for 144 hours.

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Journal of Bioethics

bioethics and the discipline's history in philosophy.

bioethics is the discipline that has not yet fully realized its potential to contribute to the development of a more just society. It remains to be seen if bioethics will be successful in its mission to promote the principles of justice and equality in health care delivery.

Ethical Obligations

and Bioethics: The Moral Basis of Bioethics

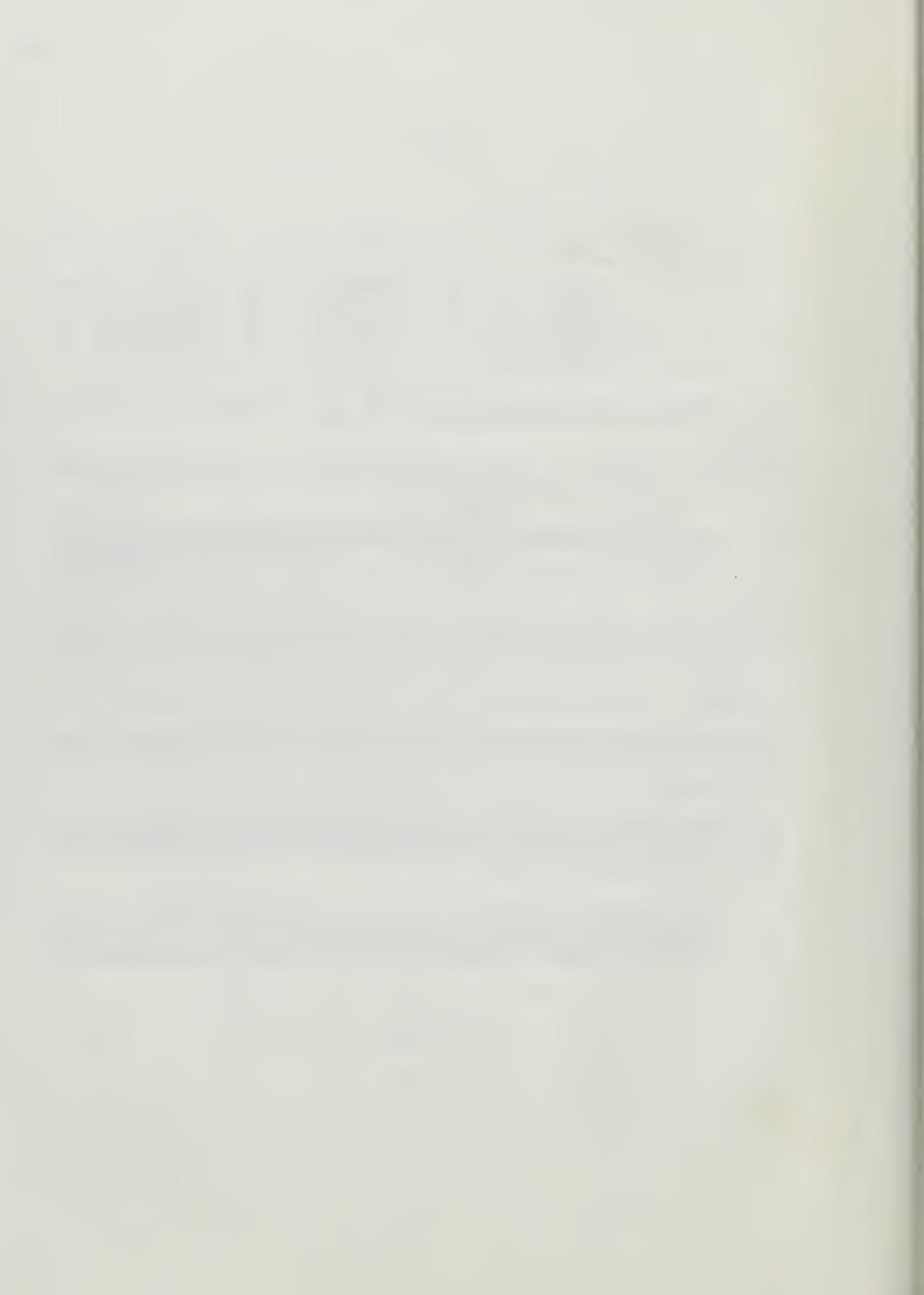
bioethics is based on a variety of ethical theories that have been developed over time. These theories include utilitarianism, deontology, virtue ethics, and social contract theory. Utilitarianism is a theory that focuses on the greatest good for the greatest number of people. Deontology is a theory that focuses on the rights and duties of individuals. Virtue ethics is a theory that focuses on the character of the individual. Social contract theory is a theory that focuses on the obligations and rights of individuals within society. These theories provide a moral basis for bioethics.

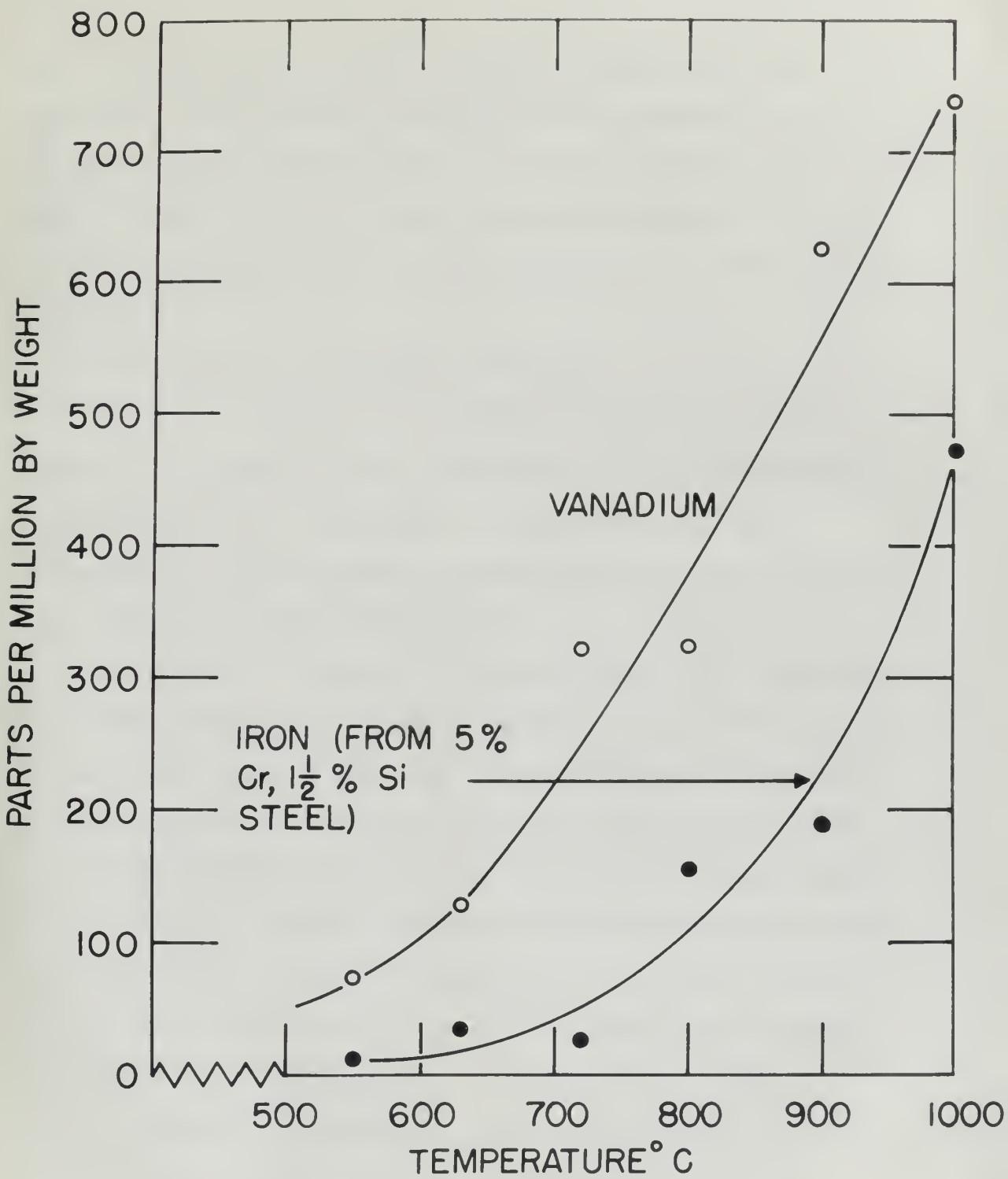
The history of bioethics is rooted in philosophy and

philosophy is a discipline that has played a role in the development of bioethics. The discipline of philosophy has contributed to the development of bioethics through the analysis of moral concepts such as justice, equality, and autonomy. These concepts have been used to evaluate the ethical implications of medical practices and to develop guidelines for the treatment of patients. The discipline of philosophy has also contributed to the development of bioethics by providing a theoretical framework for the analysis of medical practices and by providing a moral basis for the development of bioethics.

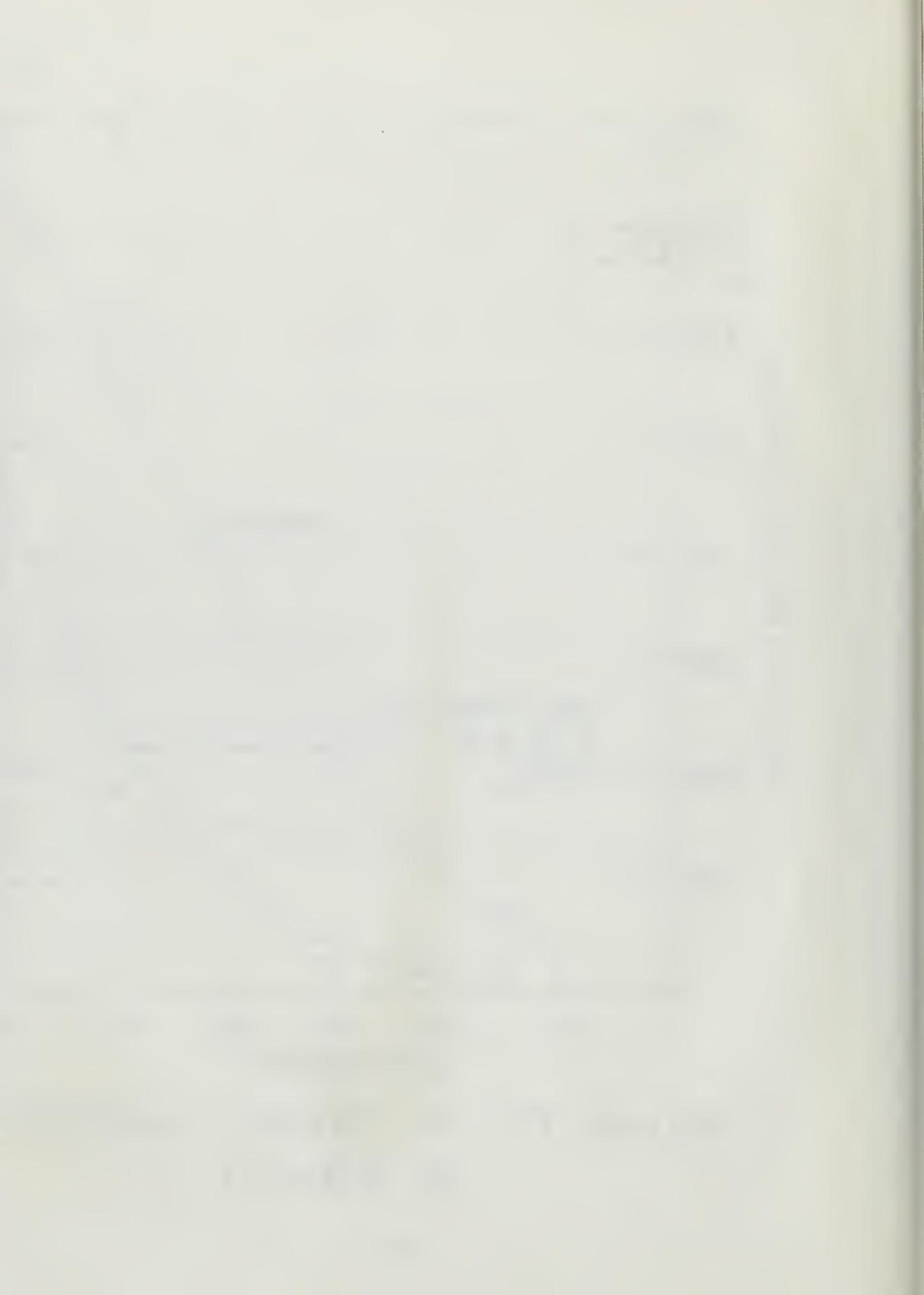
CRUCIBLE MATERIAL	LIQUID METAL CONTAINED	TEMPERATURE Degrees C	DURATION OF TEST (Hours)	DEGREE OF ATTACK	CHEMICAL ANALYSIS		TYPE OF ATTACK	DEGREE OF PENETRATION inches x10 ⁻³
					Crucible Material	Liquid Metal		
Vanadium	1-methyl 1-ethoxy	550	4	Mild	30	30	Erosion pits	0.5
Vanadium	1-methyl 1-ethoxy	550	96	Mild	30	220	Erosion pits	0.75
Vanadium	1-methyl 1-ethoxy	550	18	Mild	220	220	Erosion pits	1.1
Vanadium	1-methyl 1-ethoxy	550	24	Intermediate	30	30	Erosion pits	1.6
Vanadium	1-methyl 1-ethoxy	550	96	Intermediate	30	30	Erosion pits	1.8
Vanadium	1-methyl 1-ethoxy	550	218	Intermediate	310	310	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	550	360	Intermediate	450	370	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	550	360	Severe	20	20	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	550	360	Severe	140	140	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	550	360	Severe	30	30	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	630	96	Mild	150	150	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	630	96	Severe	110	110	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	720	96	Mild	350	410	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	720	96	Severe	160	270	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	720	144	Mild	110	290	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	720	148	Mild	110	250	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	720	192	Mild	170	170	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	800	324	Intermediate	350	340	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	800	48	Intermediate	140	130	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	800	96	Intermediate	360	410	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	800	192	Intermediate	320	310	Erosion pits	2.0
Vanadium	1-methyl 1-ethoxy	800	192	Intermediate	340	400	Small erosion pits	0.4
Vanadium	1-methyl 1-ethoxy	800	24	Severe	250	290	Small erosion pits	0.4
Vanadium	1-methyl 1-ethoxy	800	48	Severe	460	500	General surface	0
Vanadium	1-methyl 1-ethoxy	800	96	Severe	460	500	General surface	0
Vanadium	1-methyl 1-ethoxy	800	192	Severe	590	590	General surface	0
Vanadium	1-methyl 1-ethoxy	800	360	Severe	590	670	General surface	0
Vanadium	1-methyl 1-ethoxy	900	96	Mild	900	900	General surface	0
Vanadium	1-methyl 1-ethoxy	1000	24	Mild	600-920	460-440	General surface	0
Vanadium	1-methyl 1-ethoxy	1000	72	Mild	600	960	General surface	0
Vanadium	1-methyl 1-ethoxy	1000	144	Mild	550-750	870-560	General surface	0
Vanadium	1-methyl 1-ethoxy	1000	24	Severe	500	500	No attack	0
Vanadium	1-methyl 1-ethoxy	1000	72	Severe	72	28	SLight surface roughness	0.1
Vanadium	1-methyl 1-ethoxy	1000	144	Severe	72	37	SLight surface roughness	0.1
Vanadium	1-methyl 1-ethoxy	550	24	Severe	123	163	Subsurface voids	3.0
Croloy	5 S1	550	96	Severe	235	237	Subsurface voids	3.0
Croloy	5 S1	550	192	Severe	175	175	Erosion pits	0.4
Croloy	5 S1	550	360	Severe	1600	1600	Erosion pits	0.4
Croloy	5 S1	630	96	Severe	172	172	Slight surface roughness	0.1
Croloy	5 S1	720	56	Severe	173	173	Slight surface roughness	0.1
Croloy	5 S1	800	24	Severe	178	178	Subsurface voids	0.75
Croloy	5 S1	800	48	Severe	742	742	Subsurface voids	1.1
Croloy	5 S1	800	96	Severe	205	205	Subsurface voids	1.1
Croloy	5 S1	800	144	Severe	846	846	Subsurface voids	1.1
Croloy	5 S1	800	24	Severe	4900	4900	Erosion pits	0.4
Croloy	5 S1	800	96	Severe	16700	16700	Erosion pits	0.4
Croloy	5 S1	800	192	Severe	10900	10900	Erosion pits	0.4
Croloy	5 S1	800	360	Severe	19700	19700	Erosion pits	0.4
Croloy	5 S1	800	48	Severe	2500	2500	Erosion pits	0.4
Croloy	5 S1	800	96	Severe	4900	4900	Erosion pits	0.4
Croloy	5 S1	800	144	Severe	6500	6500	Erosion pits	0.4
Croloy	5 S1	800	24	Severe	19200	19200	Erosion pits	0.4
Croloy	5 S1	800	96	Severe	238	238	Erosion pits	0.4

TABLE II. Corrosion test data sheet





SOLUBILITY OF CRUCIBLE MATERIAL
IN BISMUTH



One of these two occupied a central (least agitated) position. No intermediate-agitation specimens were included in the 1000° C runs. No steel crucibles failed in test. Steel crucibles always occupied positions of most severe agitation at all temperatures and for all periods tested.

4. Wetting of crucible surfaces

Wetting of the surface in liquid-steel-cooling is considered very important to heat transfer by some authors (4). Although its importance, in the presence of pure material, is disputed, type and thoroughness of wetting were recorded.

Below 700° C wetting of the vanadium by the liquid was intermittent, the cohered bisuit being in the form of small beads loosely adherent to the surface. At 700° C film formation was evident but still intermittent, the film differing in color from the two metals from which it was formed. Between 700° C and 800° C clear patches of vanadium still appeared occasionally through the film. Above 800° C wetting was thorough - a thick film forming which was quite inseparable from the crucible sides.

In contrast, wetting in the steel crucibles did not appear below temperatures of 400° C and did not exhibit a high degree of adherence to the surface even in the 1000° C specimens. Such wetting as there was in the steel crucibles was entirely different in nature from that in vanadium crucibles.

70 million Jews of identified race have been killed at present
and all persons of all nationalities . (2) millions more
discovered have apparently been slaughtered at various times by
the Germans and their allies .

elements will not interfere with the synthesis of PEGylated molecules and can be easily removed without disrupting the polymer network. Thus, the synthesis of a PEGylated poly(ether amine) having a molecular weight of 1000 g/mol is described. The synthesis of PEGylated poly(ether amine) having a molecular weight of 1000 g/mol is described. The synthesis of PEGylated poly(ether amine) having a molecular weight of 1000 g/mol is described.

B. Corrosion test - Croloy 5 Bi by bismuth

Results are included in Table II. Photomicrographs of crucible inner surface attack are collected in Figure 14. Steel surfaces resisted attack far better than did the vanadium at all temperatures. Corrosion was relatively minor until very high temperatures were reached. Above 900° C. the steel was attacked in a peculiar way. Bismuth penetrated through a small fissure in the surface, dissolving away material to the bottom of the fissure to form a pocket or sub-surface void.

C. Corrosion tests - vanadium by sodium

Results are included in Table III. Photomicrographs of crucible inner surface attack are collected in Figure 15. Agitation was intermediate in all cases. Although results of chemical analysis are listed as parts of vanadium per million parts, by weight of sodium, this is by no means intended to portray solubility. All vanadium removed from inner surfaces of the crucible, including entrained particles eroded from the surface as well as vanadate taken into solution by the sodium, was included in the measurement.

D. Mass transfer tests

1. Physical evidence

Photographs of deposited material in the cold end of the tilt-tubes for cycling periods of 144 hours, and 336 hours are shown in Figure 16. Brittleness and fragility of the deposit caused loss and breakage in attempts to polish

the sections in several instances. There was nothing whatever in the cold end of the tube cycled for only one hour.

Deposit in the cold end of the tube cycled for 336 hours formed a pocket which trapped some of the liquid metal. The entrapped bismuth is clearly seen between the side of the vanadium tube and the deposited material in Figure 16 (b). A photomicrograph of the identical region may be seen in Figure 20. A photomicrograph of the deposit in the 168 hour test is shown in Figure 19 and a macrophotograph of this deposit is included in Figure 16 (a). The high temperature ends of the tubes which were cycled for 1, 168, and 336 hours are shown in Figure 17.

2. Chemical analysis

Chemical analysis of the deposited material from the low temperature ends of the tilt tubes are listed in Table III. The composition of the phases and the relative amounts of each present are not revealed by chemical analysis. The deposited material was loosely bonded to the tube walls and easily broken free.

3. Metallographic examination

Figure 18 is a collection of photomicrographs of the high temperature ends of the tilt-tubes showing attack by the bismuth. Figures 19 and 20 are photomicrographs of the deposit in the cold end showing the microstructure.

4. X-ray spectrographic analysis

In addition to characteristic lines of vanadium and bismuth, two strong lines of an unidentified substance are present in the X-ray spectrograph of the 168 hour cold end

—*Final judgment* *After* *transcript* *presented* *Lawyers* *and* *members* *and*
—*which* *have* *been* *read* *and* *discussed* *more* *than* *the* *law* *allows* *and* *now*
recommend *that* *the* *Senate* *reject* *the* *law* *unless* *and* *not* *otherwise*
—*and* *that* *Justice* *Minister* *and* *the* *other* *responsible* *ministers* *thereby* *be* *informed*
and *be* *asked* *not* *presented* *from* *anywhere* *an* *official* *recommendation*
—*(ii)* *At* *present* *no* *Indigenous* *settlements* *will* *have* *used* *substantial*
amounts *of* *gas* *under* *conditions* *which* *do* *not* *conform* *to* *the* *recommendations* *of*
the *law* *and* *the* *lawyers* *recommend* *that* *the* *Government* *do* *not*
—*allow* *the* *development* *or* *use* *of* *any* *gas* *under* *such* *conditions*

Die Hypothesenstudie in umfassenderer Art und Weise erweist
dass durch die gezielte Anwendung von "soziale Unterstützung" kann nicht
nur die wahrgenommene Belastung eines Betriebs sozialen Bereichs verringert werden
sondern auch die Arbeitszufriedenheit und Arbeitsleid senken. Also ist es ratsam
durch die Anwendung von "sozialer Unterstützung" zu einer Reduzierung
der Belastungen im Betrieb zu kommen.

Duration of test (hours)	Temperature of hot end (degrees C)	Temperature of cold end (degrees C)	Free Liquid Metal Remaining (per cent)	Chemical Analysis of cold end deposit
1	900	300	98	no deposit
163	900	390	35	3.06% vanadium 96.94% bismuth
336	900	320	8	6.25% vanadium 93.75% bismuth
503	900	300	2	4.65% vanadium 93.35% bismuth

TABLE III Data on Mass Transfer Test

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deposit. A vanadium-bismuth alloy is clearly indicated. Since extra lines introduced by this alloy are so few, probable existence of a cubic phase is inferred.

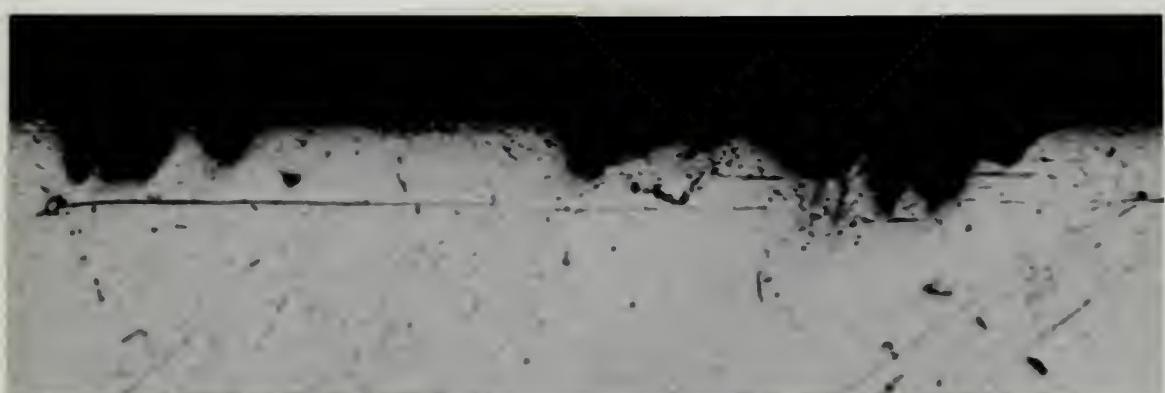
Additional details of each observation is left until
such time that the important basic data can
be obtained at which time it is to be submitted.





(a)

Temperature : 550°
Period : 24 hours
Agitation : mild



(b)

Temperature : 550°
Period : 24 hours
Agitation : severe

Figure 5

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 600X.

$\lambda = \text{Im} z^{\frac{1}{2}} \cos \pi - \theta$

Table 1
values of
 λ for
various

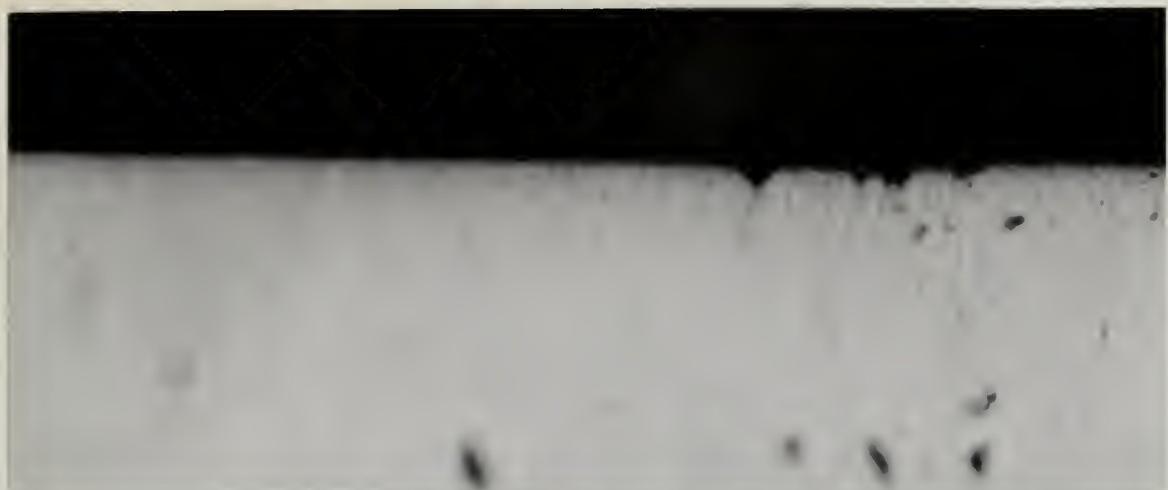
(a)

Table 2
values of
 λ for
various

(b)

values

which can be compared with the values obtained by another method
(e.g. numerical integration) if required.



(a)

Temperature : 550°
Period : 360 hours
Agitation : mild



(b)

Temperature : 550°
Period : 360 hours
Agitation : severe

Figure 6

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 600X.

300 : ~~plastering~~
 2100 : ~~boiling~~
 650 : ~~molding~~

(a)

300 : ~~exterior~~
 2100 : ~~boiling~~
 650 : ~~molding~~

(d)

3 surr

paints too solid too white to cover sooty to sooty smoke
 wood sooty blackish brownish



(a)

Temperature : 630°C
Period : 96 hours
Agitation : mild



(b)

Temperature : 630°C
Period : 96 hours
Agitation : severe

Figure 7

Cross section of interior surface of vanadium crucible containing bismuth. Unetched. Magnification 600X.

5 - 34 = 25) - A

5	1	00000000
- 3	1	00000000
4	1	00000000

(a)

5 - 34 = 25) - A

5	1	00000000
- 3	1	00000000
4	1	00000000

(b)

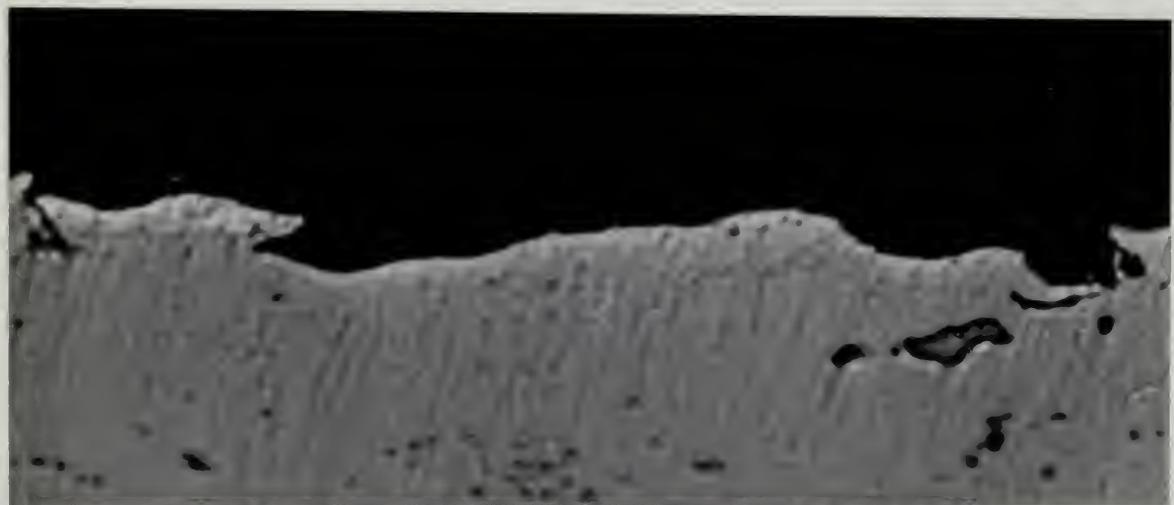
5 - 34
1 00000000

Subtraction without borrowing to subtract 34 from 50
and 34 from 50000000



(a)

Temperature : 720°C
Period : 96 hours
Agitation : mild



(b)

Temperature : 720°C
Period : 96 hours
Agitation : severe

Figure 5

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 600X.

$$Y = \gamma \tilde{f}(\theta) - \beta \zeta + \omega$$

Table 1
Statistical
Results

(a)

$$\hat{\theta} = \hat{\alpha} + \hat{\beta} \hat{y} + \hat{\epsilon}$$

Table 2
Statistical
Results

(b)

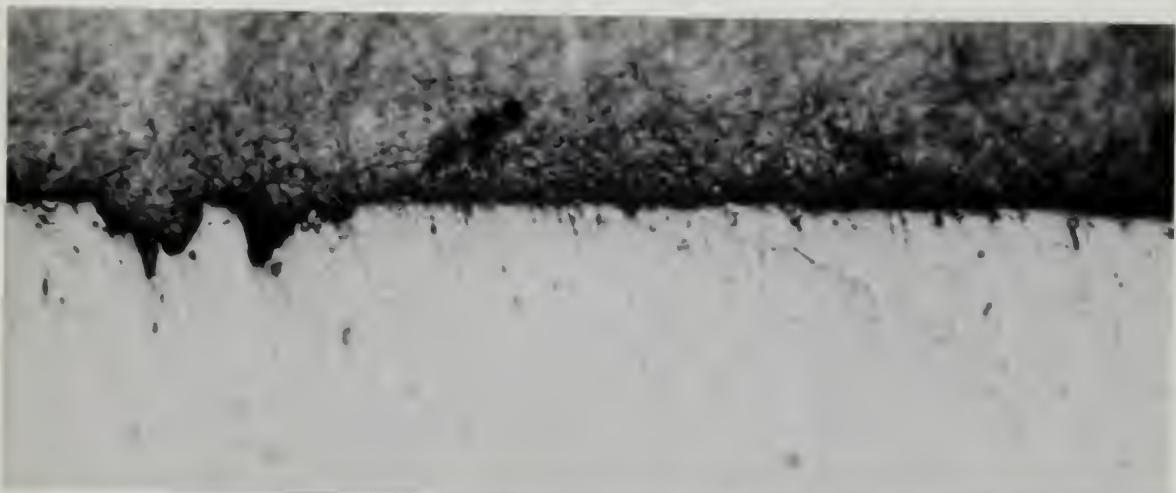
$\hat{\theta} = \hat{\alpha} + \hat{\beta} \hat{y}$

Statistical significance test may be carried out to check whether
the coefficient of \hat{y} is statistically significant or not.



(a)

Temperature : 800°C
Period : 24 hours
Agitation : mild



(b)

Temperature : 800°C
Period : 24 hours
Agitation : severe

Figure 9

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 600X.

1970-71
1971-72

2

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मार्च २६
संग्रह

4

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particulars of which nothing can be said save that he has been engaged in the construction of a bridge.



(a)

Temperature : 500°C
Period : 338 hours
Agitation : mild



(b)

Temperature : 500°C
Period : 338 hours
Agitation : intermediate (substituted for severely agitated specimen, which failed)

Figure 10

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 600X.

$\lambda_0 - \lambda_1 = -\lambda_2 + h$

$\gamma^0(x)$ is smooth
at $x=0$
 $\gamma^0(x)$ is analytic

(a)

$\lambda_0 - \lambda_1 = -\lambda_2 + h$

$\gamma^0(x)$ is smooth
at $x=0$
and has a positive derivative at $x=0$
and has a negative derivative
(positive slope)

(d)

DL example

Consider two different solutions to the same differential equation with different initial conditions. Then we have



(a)

Temperature : 900°C
Period : 96 hours
Agitation : mild



(b)

Temperature : 900°C
Period : 96 hours
Agitation : severe

Figure 11

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 300X.

6000 : 00000000
5000 : 00000000
4000 : 00000000

(a)

5000 : 00000000
4000 : 00000000
3000 : 00000000

(b)

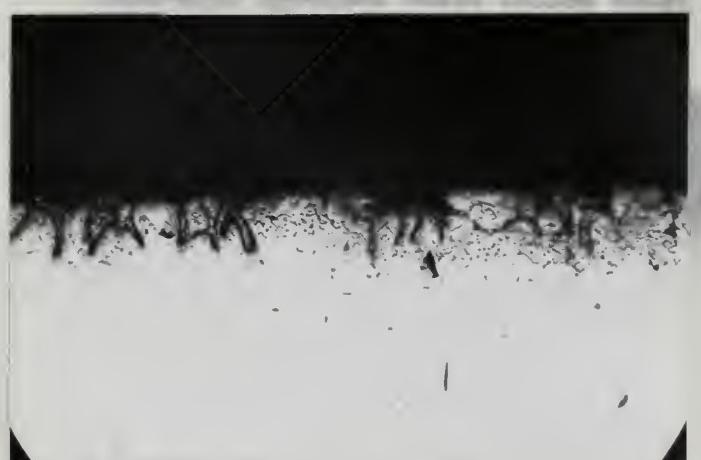
11 0000

particular conditions will have to be found to obtain good
and uniform results.



(a)

Temperature : 1000°C
Period : 24 hours
Agitation : mild



(b)

Temperature : 1000°C
Period : 24 hours
Agitation : severe

Figure 12

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 300X.

1990-1991
Year 1990-91
1991-92

(G)

4" x 6" 100
2" x 4" 100
1" x 2" 100

(4)

卷之三

~~Section 225. Any unitary system related to another unitary system will have a corresponding relationship between them.~~



(a)

Temperature : 1000°C
Period : 72 hours
Agitation : mild

Note: 72-hour specimen substituted for
144-hour specimen which failed under test.



(b)

Temperature : 1000°C
Period : 72 hours
Agitation : severe

Note: 72-hour specimen substituted for
144-hour specimen which failed under test.

Figure 13

Cross section of interior surface of vanadium crucibles containing bismuth. Unetched. Magnification 300X.

0.001 : 0.0000000000000001
0.0001 : 0.0000000000000001
0.01 : 0.0000000000000001

(a)

not reflecting any known reality; rather
that reality belongs to the imaginary world.

0.001 : 0.0000000000000001
0.0001 : 0.0000000000000001
0.01 : 0.0000000000000001

(g)

not reflecting any known reality; rather
that reality belongs to the imaginary world.

Q.E.D.

What we have shown is that the probability of getting a random sequence of length n with all digits being 1's is 10^{-n} .

(gross section of interior surface of steel (Cr alloy 5 Si) crucibles containing bismuth. Unetched. Magnification 300X.)

(a) Temperature : 550°C
Period : 24 hours
Agitation : severe



(b) Temperature : 600°C
Period : 24 hours
Agitation : severe



(c) Temperature : 800°C
Period : 338 hours
Agitation : severe



(d) Temperature : 1000°C
Period : 24 hours
Agitation : severe



(e) Temperature : 1000°C
Period : 1½ hours
Agitation : severe

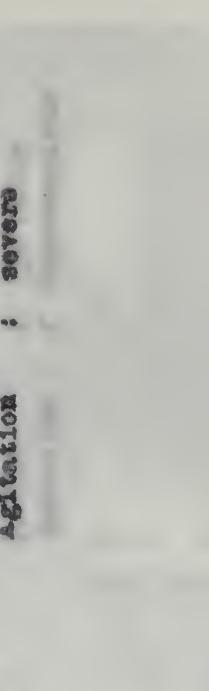
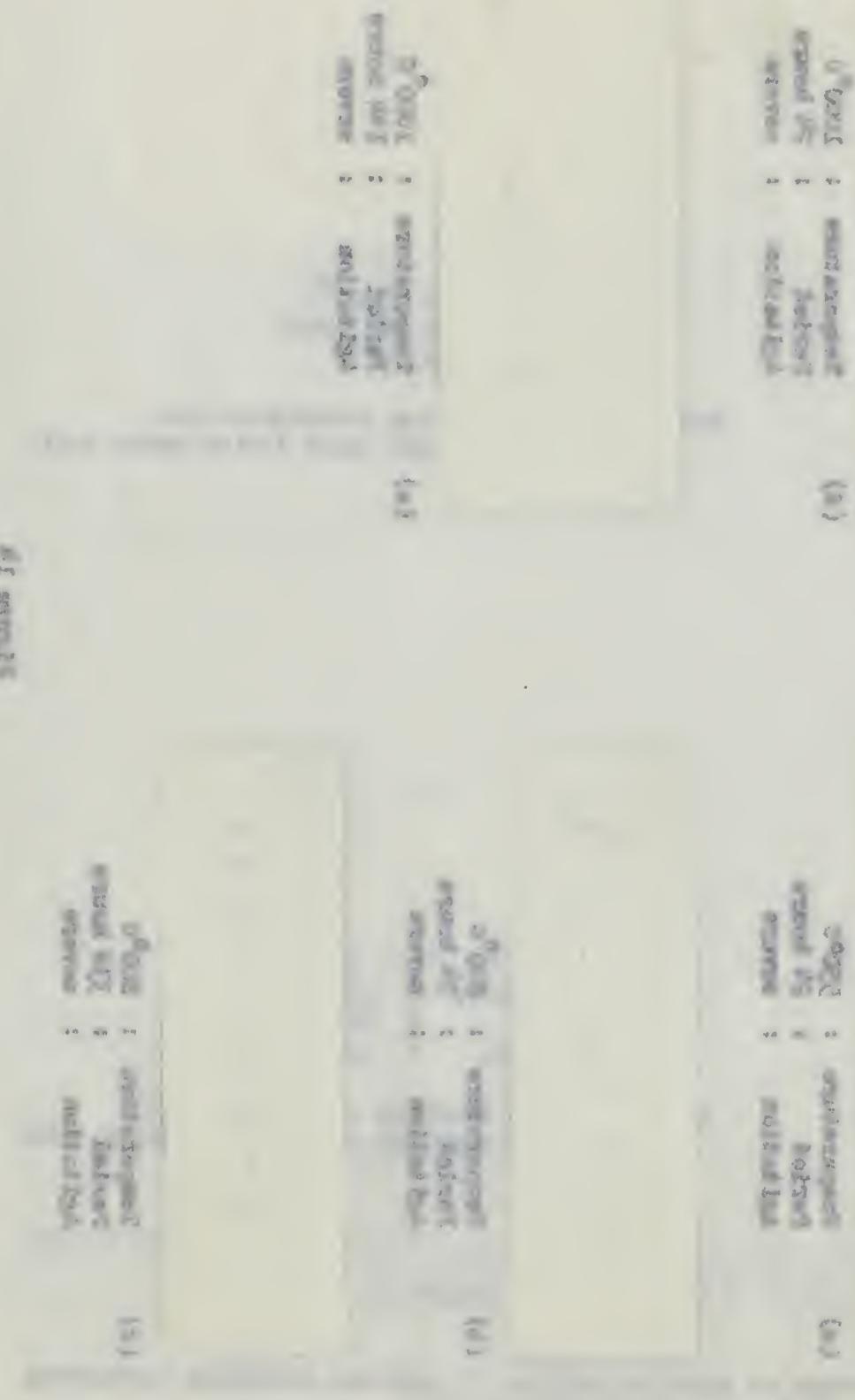


Figure 14

१०७



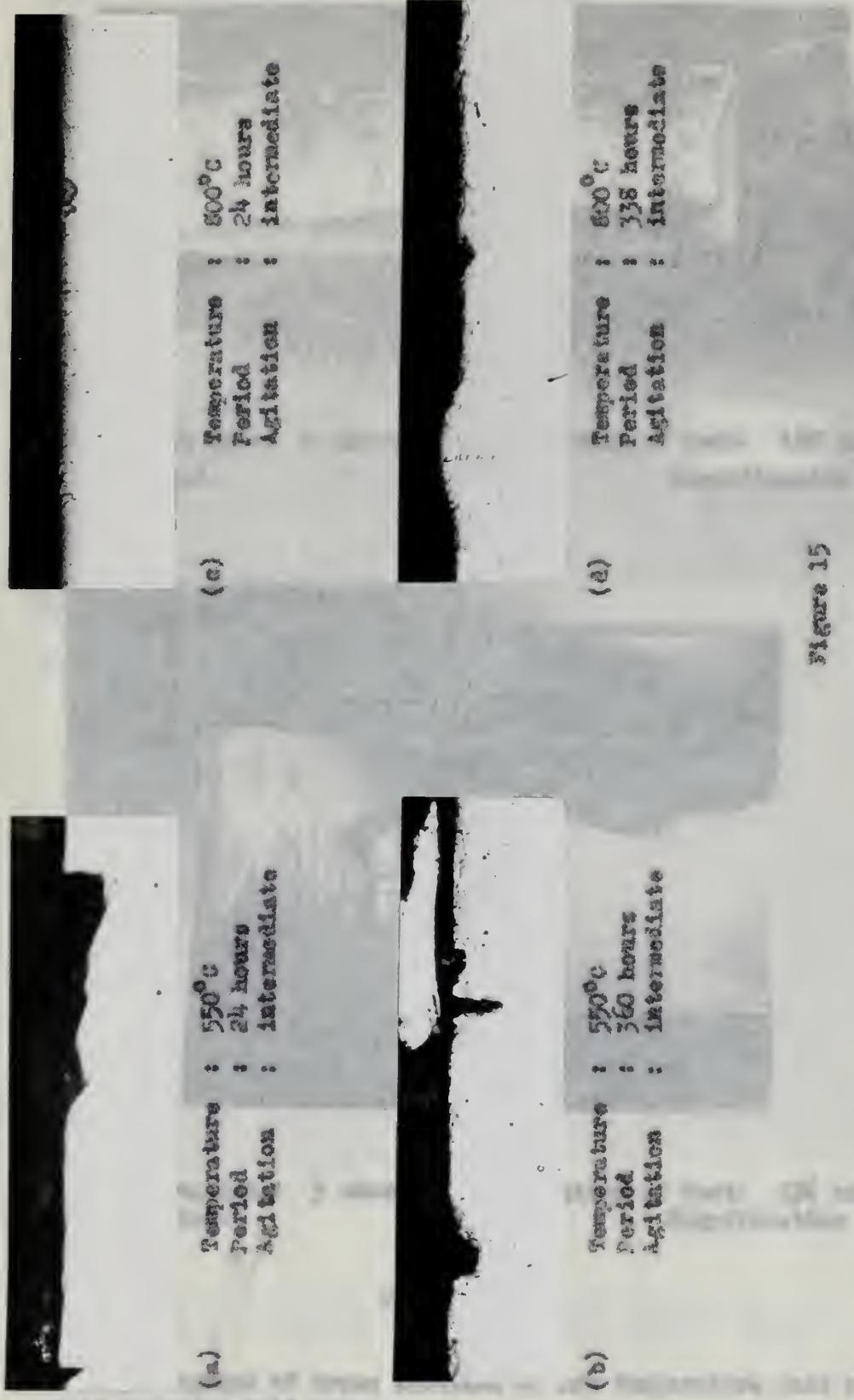


Figure 15

Cross section of interior surface of vaneedine crucibles containing rediae. Etched. Magnification 300%.

1. 1000
2. 1000
3. 1000
4. 1000
5. 1000
6. 1000

(a)

1. 1000
2. 1000
3. 1000
4. 1000
5. 1000
6. 1000

(b)

1. 1000
2. 1000
3. 1000
4. 1000
5. 1000
6. 1000

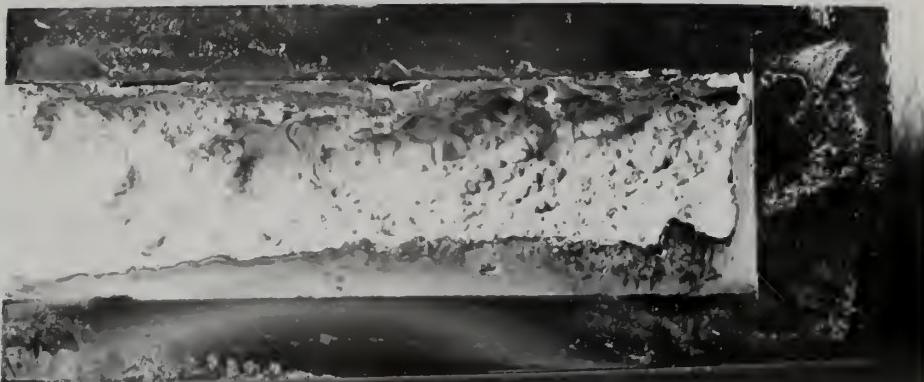
(c)

1. 1000
2. 1000
3. 1000
4. 1000
5. 1000
6. 1000

(d)

1. 1000
2. 1000
3. 1000
4. 1000
5. 1000
6. 1000

(e)



(a) Cycling Rate: 5 minutes. Duration of Test: 168 hours.
Unetched. Magnification : 4X



(b) Cycling Rate: 5 minutes. Duration of Test: 336 hours.
Unetched. Magnification : 6X

Figure 16

Macrophotograph of cross sections of low temperature ends of mass transfer tilt tubes.

and will have to return
to : solidus

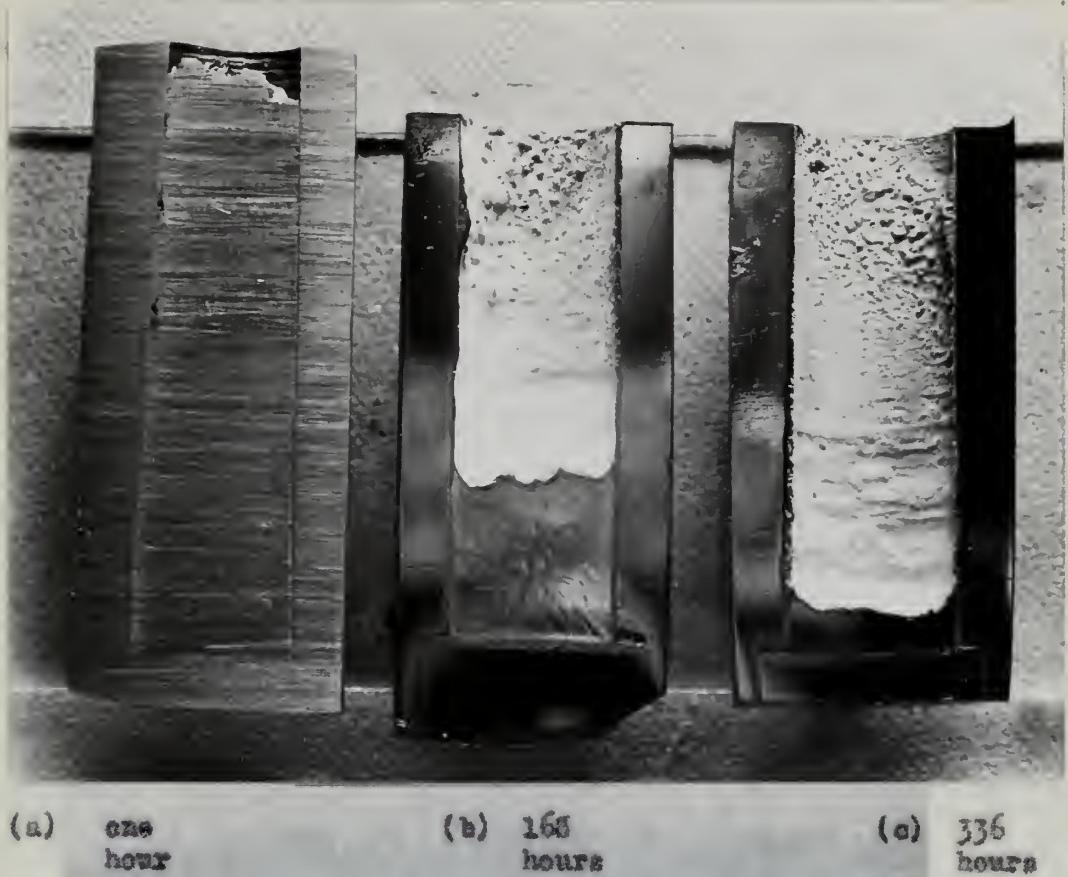
return to solidus

and if we want
to get rid of

return to solidus

at once

to stop working and to go back to dependence
on the old system again



(a) one
hour

(b) 168
hours

(c) 336
hours

Figure 17

Macrophotographs of high temperature ends of tilt tubes cycled for 1, 168, and 336 hours. Unnotched. Magnification: 3X.

(b) Unnotched at 336 hours

Figure 18

Microphotographs of high temperature ends of unnotched tilt tubes at 336 hours. Unnotched. Magnification: 300X.

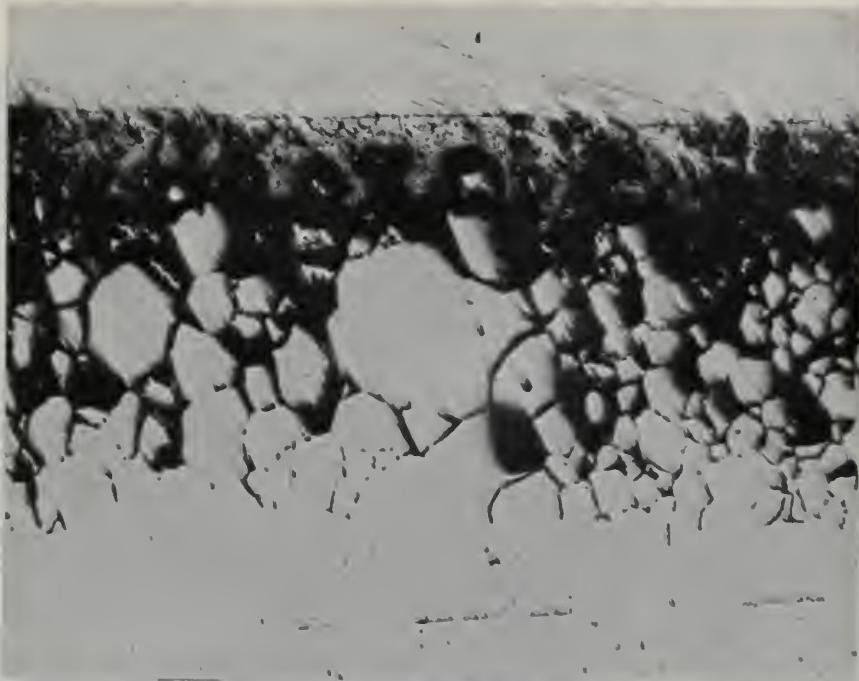
EGG (a)
eggs

EGG (b)
eggs

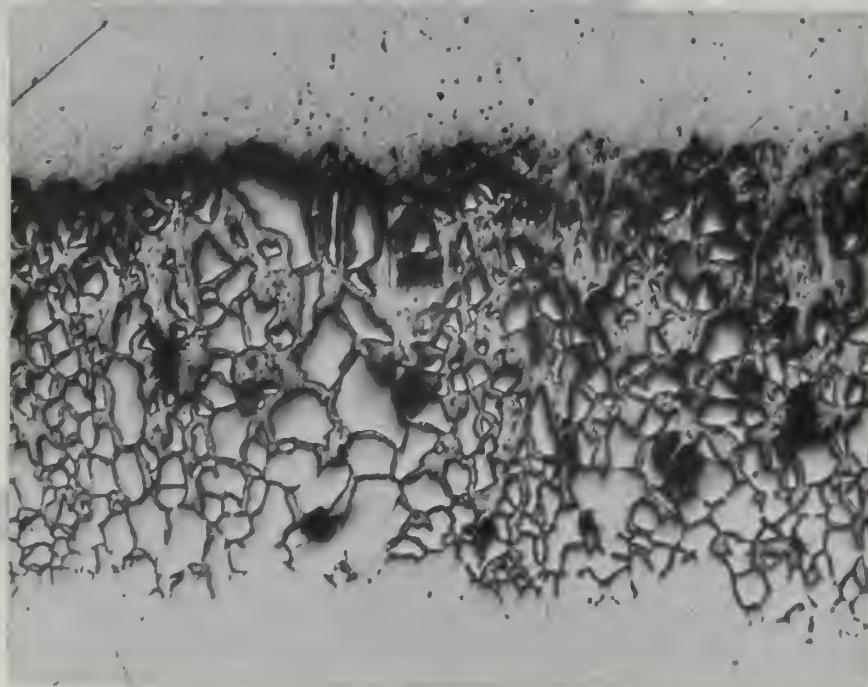
EGG (c)
eggs

7. EGG

below and this is also mentioned that the highest frequency
of molt offizes. However, around 10% has still not yet



(a) Duration of Test: 168 hours.



(b) Duration of Test: 336 hours.

Figure 18

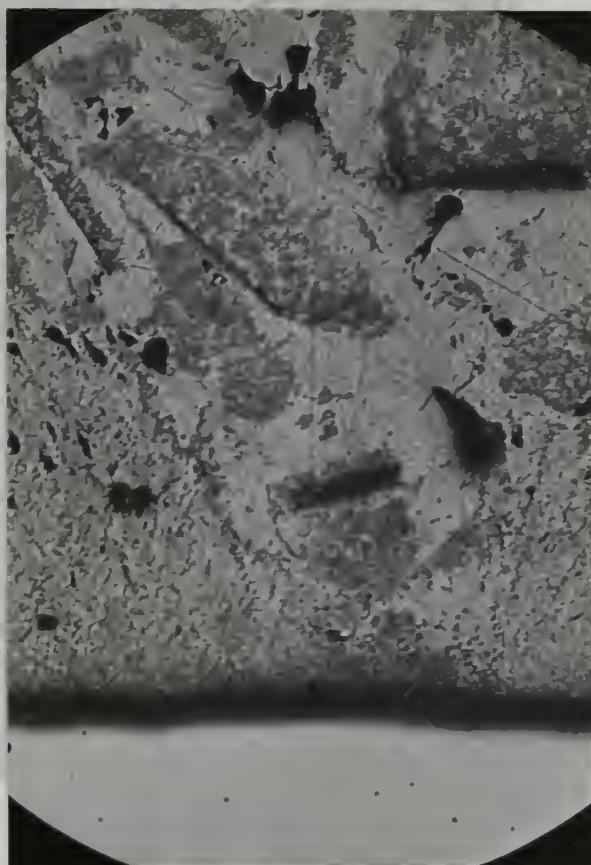
Cross section of high temperature ends of mass-transfer
tilt tubes. Unetched. Magnification: 150X.

dated this twenty two thousand (22)

dated this twenty two thousand (22)

By witness

Yours sincerely for the statement made in witness name
John McDonald, Notary Public, State of New



Material
deposited
in
cold end
of
tilt tube.

Vanadium

Figure 19

Photomicrograph of deposit in low temperature end of tilt tube.
Duration of Test: 168 hours. Unetched. Magnification: 90X.

54

Lathes

Collaboration

AI

Two Kinds

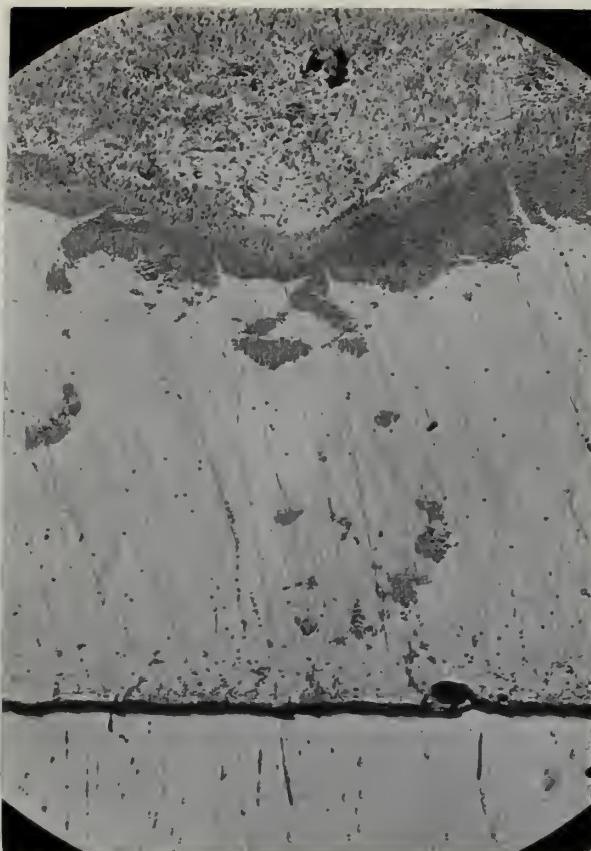
2a

adult child

Collaboration

of adult

adult child is his own self as it tends to be preoccupied
and incapable, cannot reward child's need to control



Material deposited
in
cold end of tube.

Intrapped

Liquid

Metal

Vanadium

Figure 20

Photomicrograph of deposit in low temperature end of tilt tube.
Duration of Test: 336 hours. Unetched. Magnification: 90X

Brachionus californicus

— 100

reicht bei den Ringen

— 100

Brachionus

californicus

Californicus

— und diese ist am gewöhnlichsten und am allgemeinsten vorkommenden und am häufigsten vorkommenden Brachionus, wenn wir das heißt, der auf dem Lande

V. DISCUSSION OF RESULTS

A. Corrosion tests

1. Solubility tests

The solubility of iron in molten bismuth was low up to about 750°C above which it is seen to increase rapidly as shown in Figure 4. The vanadium solubility curve, within the temperature range tested, exhibits much greater linearity, not having a particular temperature above which corrosion accelerates rapidly. Neither, on the other hand, does it have a temperature region in which its solubility characteristics may be considered good. The almost linear increase of solubility with temperature establishes conditions favorable to thermal gradient mass transport at any selected set of operating temperatures. Solubility of vanadium in bismuth was greater than that of iron in bismuth at all temperatures tested.

2. Corrosion and corrosion-erosion

Marked difference in surface attack at low temperatures are evident (Figures 5 and 6) between specimens which had gentle agitation and those which had severe agitation. At first, attack increases as temperature is increased, showing definite intergranular attack at 630°C (Figure 7). However, intergranular attack diminishes at the temperatures at which intermetallic film formation becomes manifest. At 720°C , one of the specimens shows film formation with adherent bismuth. The other did not form a film and

meit van verschillende vertrekken en met de verschillende cultuur- en historische contexten die deze gebieden hebben. De verschillende culturen en historische perioden hebben verschillende tradities en waarden die invloed hebben op de manier waarop mensen leven en denken. Daarom is het belangrijk om respect te hebben voor de verschillende cultuur en historische contexten en om te proberen deze te begrijpen en te尊重eren.

was corroded (Figure F). At 800° C intermetallic film formation was fairly consistent and the surfaces were only slightly damaged. At 900° C and above, intense intergranular attack again becomes evident, reaching proportions of 500 mils per year at 1000° C. Measurements of penetration at these temperatures is rather arbitrary since damage is often so advanced as to make the location of the original surface level a matter of conjecture. Attack, at 1000° C, appears more severe for specimens agitated mildly than for highly agitated specimens. This may be caused by mechanical breaking away, under severe agitation, of grains whose boundaries have been chemically attacked, giving the appearance of less penetration.

B. Corrosion-erosion of vanadium by sodium

Erosion at low temperature is again evident though generally to a lesser degree than that caused by bismuth. Attack was worse at 550° C than at 800° C, amounting to 127,000 parts per million at 550° in 360 hours. The surfaces at 800° are characterized by bumps or protuberances. These bumps are believed to be localized points resistive to corrosion attack, possibly due to impurities present. Attack is believed to be a general surface attack, leaving the resistive points salient from the lowered surface.

Though this set of tests are of a rough and possibly inconclusive nature, it appears that vanadium does not hold much promise as a container material for molten sodium.

C. Thermal gradient mass transport tests

Evidence of mass transfer under the extreme conditions imposed in this test is incontrovertible. After completion of the tests it was evident that more bismuth should have been introduced into the mass-transfer tubes. Upon sectioning the tube after a test period of 336 hours, almost all bismuth was depleted (see Figure 17). A large proportion of it had apparently gone into a stalagmitic growth in the center of the tube adhering to the lower side and to the end. The growth was brittle and of a very fragile nature and was broken in attempting to prepare it for photographing. A considerable portion of the bismuth had apparently gone into a gold-colored layer adhering to the walls of the tube beginning at about the center of the tube and becoming quite thick at the high temperature end. The appearance of the film may be noted in Figure 17.

Corrosion attack of the prepared surface at the hot end of the mass transfer tubes was intergranular in nature and was so severe for the cycling periods of 168 and 336 hours that the lowest power available in the microscope barely included the full depth of penetration in its field. There was no apparent attack in the tube operated for only one hour. In the 500 hour test, penetration was visible to the naked eye (about 1.5 millimeters).

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VI CONCLUSIONS

A. Commercial quality high-ductility vanadium is not a suitable container material for high purity molten bismuth because of the following demonstrated properties:

1. low resistance to mechanical attack at temperatures between 550 and 700°C
2. High solubility in molten bismuth
3. severe inter- granular corrosion at high temperatures
4. susceptibility to thermal gradient mass transport.
(Convection currents of bismuth in a vanadium circuit may be expected to produce plugging in the cold portion of the loop and severe attack in the hot portion).

B. Commercial quality vanadium shows little promise as a container material for molten sodium.

Background

A 2003 study without controlled cycling intervention, a 2005 study of 2500 participants from 10 countries, and a 2006 study of 1000 participants from 10 countries found that cycling 30 min per day was associated with a 30% reduction in all-cause mortality and a 20% reduction in cardiovascular mortality.

Objectives

The aim of this study was to compare the effects of cycling 30 min per day with those of walking 30 min per day on all-cause mortality and cardiovascular mortality.

Principle: All-cause mortality, Framed of 100000 participants in 11 countries (26 countries included) at approximately 50 years of age during 10 years. Mortality data were from the World Health Organization and the United Nations and were collected from 1990 to 2000. Mortality data and working time data were obtained from the World Health Organization and the United Nations.

Design: A cross-sectional study comparing the mortality rates of people who cycled 30 min per day with those of people who walked 30 min per day. The study used a multivariate regression model to control for potential confounding factors such as age, sex, education level, income, smoking status, alcohol consumption, physical activity, diet, and exercise. The study also controlled for other factors such as weather, traffic, and urbanization.

VII CONCLUSIONS.

The light weight, abundance, high strength-weight ratio, high-temperature strength, and reasonable fabrication characteristics (2, 6), coupled with a small neutron absorption cross-section (2) make vanadium a highly desirable material for use in nuclear reactors, (particularly in fast reactors). In order to evaluate its feasibility for use in a fast homogeneous reactor further research, using the techniques of the foregoing experiments, could be continued along three general lines:

1. evaluation of vanadium alloys, such as a vanadium-2% zirconium alloy (2), as container materials for bismuth
2. evaluation of pure vanadium and vanadium alloys as container materials for other easily-liquified metals which have low neutron absorption cross sections, such as gallium, lead, lithium, thallium, tin, and low-melting eutectics of lead-bismuth (3)
3. evaluation of inhibitors, such as zirconium and magnesium, in a vanadium-bismuth system to eliminate the selective attack at the grain boundaries and reduce the rate of solution.

Appendix A

Furnace Design and Construction

Design parameters for the furnace were imposed by an unusual set of circumstances dictated by the testing procedure decided upon. Because of the shocks and mechanical stresses to which the furnace would be subjected, it was imperative that the windings be exceptionally rugged. The physical size of the furnace had to be fairly small so that the teeter-board dimensions would be reasonable, yet the isothermal region within the furnace had to be relatively large. The latter criterion necessitated multiple windings with the individual windings controllable independently. In the presence of a constant-power-per-turn winding, temperature in this type of furnace usually distributes itself along a cosine curve on the longitudinal axis because of the maximum heat loss to the ends of the core. To compensate for this, windings were designed with maximum power per turn at the ends and minimum at the center. For rigidity and high temperature strength, a very heavy wire, twelve gauge was decided upon. The large diameter and low resistance of the wire enforced the use of transformers to provide low-voltage high-power sources. Five zones of controllable heating were decided upon in order to insure that constant temperature could be maintained over a large portion of the furnace length. Since the transformers provided isolation of the power sources, adjacent windings shared lead-in wires and internal wiring was kept to a minimum. The twelve gauge wire was wound on a three inch diameter Alundum refractory tube, 18 inches in length, grooved

6 turns to the inch. The end windings, consisting of 14 turns each, were energized by 24 volts (nominal voltage). These windings extended no further than the end plugs of the core, and were intended to heat the plugs and prevent heat loss and consequent temperature drop at the ends. The actual interior portion of the furnace was heated by three windings of 22, 34, and 22 turns respectively, energized by voltages (nominal) of 30, 36, and 30 volts. The primary of each isolation and step-down transformer was energized by a Variac variable voltage transformer by which the output voltage could be varied from 0 to 117 $\frac{1}{2}$ of nominal voltage. A chromel-alumel thermocouple was placed directly adjacent to the center of the winding and used for operation of a Leeds and Northrup Micromax controller. The controller operated a holding type relay (to prevent relay chatter) which, during demand periods, shorted out a large Variac used as a variable inductance in series with all Variares controlling furnace region isolation transformers. During non-demand periods the voltage to the isolation transformers was reduced by the drop across the series inductance. This method of control was the only one of the three tried which did not result in excessive relay contact arcing due to inductive effects of the five isolation transformers in parallel. A circuit diagram of the furnace winding and control circuit is shown in Figure 21.

Leads from the individual windings were welded to the common points of the windings and consisted of double lengths of 12 gauge wire spot welded together every two inches. Ends of the double wires were welded

to studs which passed through the transite furnace supports and were used as connection points. Using equal power in all windings (not equal power per turn) the furnace temperature between end plugs was within ten per cent of the center set temperature (maintained by controller) upon first heating. By adjustment of voltage to the individual zones, temperatures within the furnace could be maintained to within plus or minus $1/2\%$ at all points.

The frame for the furnace tester-board (Figure 1) was made using four-in. channel beams and was supported, at first, in brass sleeve bearings. The weight of the furnace caused binding of the sleeve bearings. This interfered with the bouncing action intended to apply severe agitation to the end-mounted specimens. Large ball bearings were substituted for the sleeve bearings and no further bearing difficulty was experienced.

For the corrosion tests the microswitch and operating cam shown Figure 1 were not used. The motor speed controller was set to bounce the furnace on the springs once every 5 seconds.

For the mass transfer tests the bouncing action of the furnace tester-board was damped out, and the oscillation period reduced to a ten minute cycle.

Oscillation frequency was reduced by periodic interruption of power to the motor by an electronic interval timer. The circuit diagram of the interval timer is shown in Figure 22. The cam operated the microswitch as the furnace tester-board went through horizontal dead

center. The power was then cut off to the motor, but inertia kept the motor going for a few more turns. From this point on the furnace dropped freely onto a damped stop. At the end of the timed interval the intermittent lift action of the operating mechanism allowed the motor to build up to speed under no load conditions.

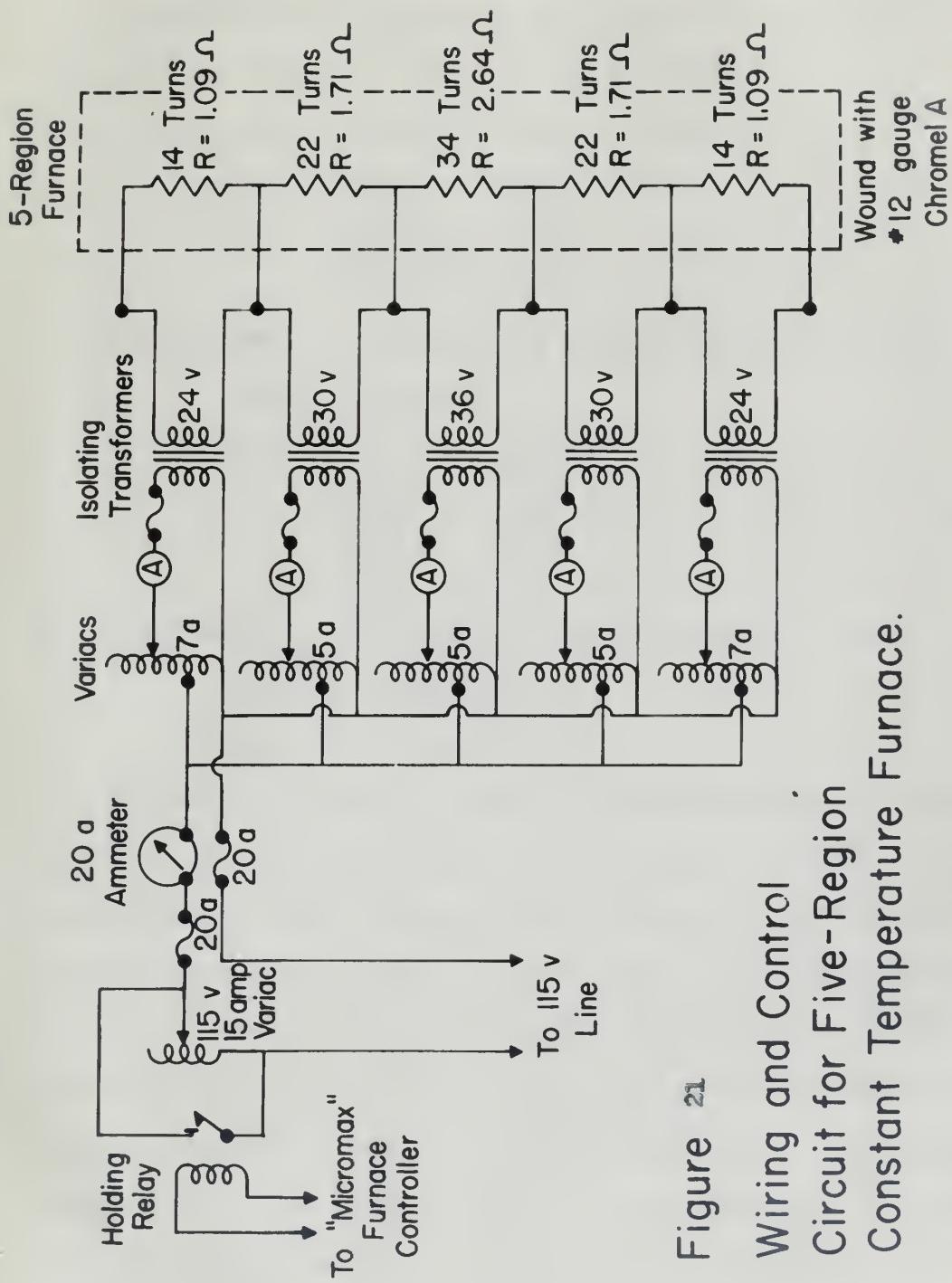
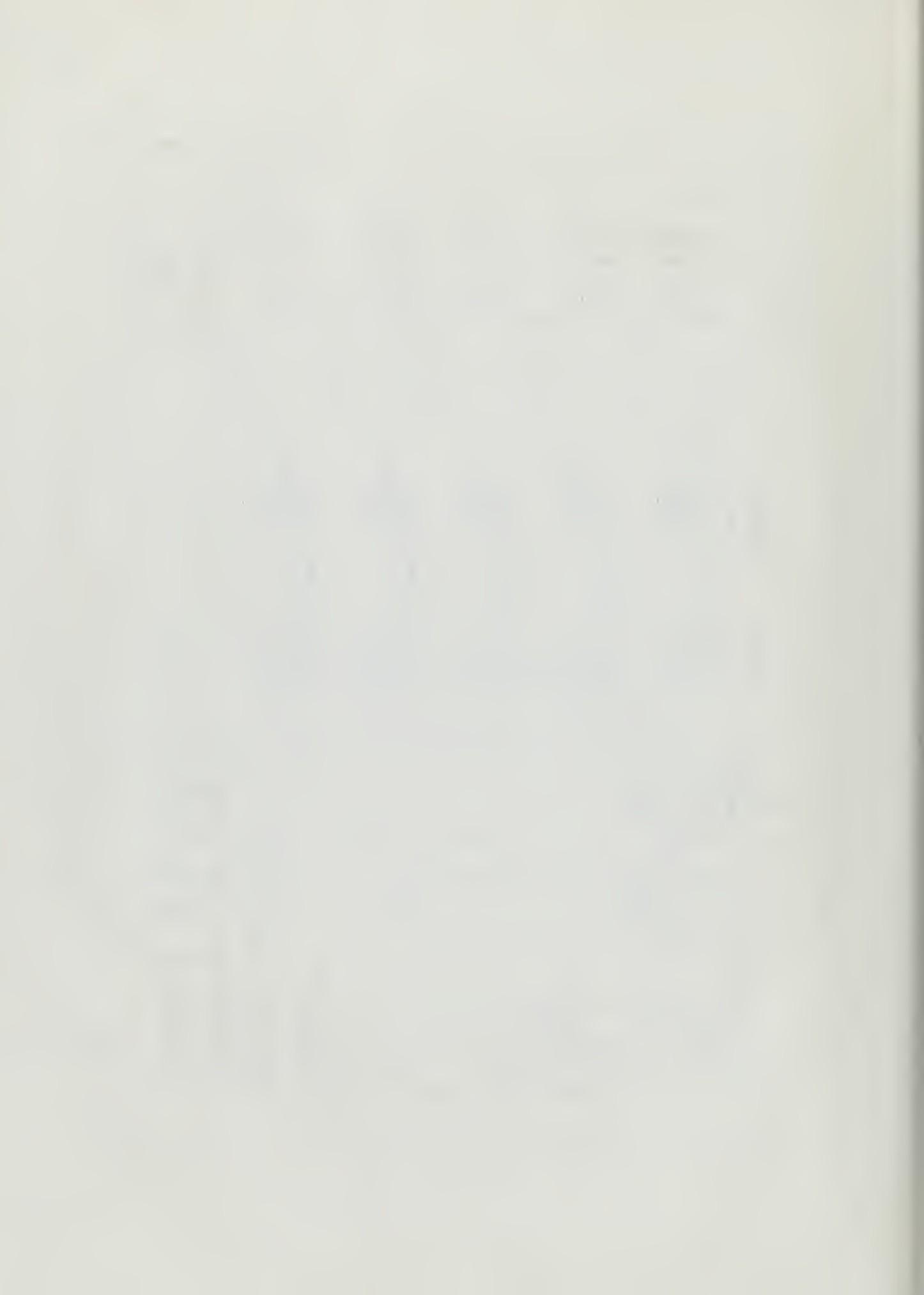


Figure 21
Wiring and Control
Circuit for Five-Region
Constant Temperature Furnace.



APPENDIX B

Crucible Construction, Leading, and Welding

Specifications for the starting materials are as follows:

1. vanadium metal (Electro-Metallurgical Co.)

form: chips, 1/4 inch by 12 mesh

analysis :	carbon	0.05%
	oxygen	0.056%
	hydrogen	0.01%
	nitrogen	0.06%

2. bismuth metal (Mallinckrodt Chemical Works)

form: granulated

analysis :	arsenic	0.006%
	copper	0.005%
	iron	0.00%
	silver	0.005%
	zinc	0.00%

3. sodium metal (Mallinckrodt Chemical Works)

form: solid billets

analysis : not available

The vanadium metal chips were cold compacted in a steel can at 32,000 pounds per square inch. The can was then evacuated, sealed off and extruded at 1950° F through a 0.7 inch die, the extrusion constant being 64,000 pounds per square inch. The first extrusion was largely unusable because of insufficient back pressure, resulting in cracks and fissures in the rod. Subsequent extrusions were made with a nickel plug at the front of the extrusion billet. The nickel, not being as soft as the steel at 1950° F greatly increased the initial back pressure and resulted in an extrusion of much better quality. The rods were swaged lightly for straightening, then turned down on a lathe to the final outer diameter, thereby removing the steel jacket.

De zuid- en Zuidoost-Europese leefgebieden van de soort zijn voornamelijk gebieden met een warm en droog klimaat. De soort komt voor in de zuidelijke en oostelijke delen van Europa, maar ook in de noordelijke delen van de Balkan en in de Middellandse Zee. In Noord-Europa is de soort vooral te vinden in de zuidelijke en oostelijke delen van het land, maar ook in de westelijke delen van Denemarken, Noorwegen en Zweden. In Scandinavië komt de soort voor in de zuidelijke en oostelijke delen van het land, maar ook in de westelijke delen van Noorwegen en Zweden. In Noord-Europa is de soort vooral te vinden in de zuidelijke en oostelijke delen van het land, maar ook in de westelijke delen van Denemarken, Noorwegen en Zweden. In Scandinavië komt de soort voor in de zuidelijke en oostelijke delen van het land, maar ook in de westelijke delen van Noorwegen en Zweden.

Discarding the ends of these rods (which were contaminated with nickel at the front and with steel at the back) left a solid vanadium rod. Sectioning of the rods into crucible lengths was followed by the drilling out of each section to proper depth. Interior surfaces were polished with fine emery cloth. Caps for the crucibles were prepared from the same material, the inner surface being given a metallographic polish. Dimensions of the assembled crucible are included in Figure 2. Just prior to charging these crucibles with bismuth metal, they were thoroughly cleaned by pickling in concentrated nitric acid.

It was felt that the metallic bismuth, despite its high purity, should not be placed directly into the vanadium crucibles due to the large surface area in its granulated form and the existence, at room temperature, of an oxide film on bismuth. The surface area was greatly reduced by melting down the granules in a graphite crucible (in air) and pipetting unoxidized metal from below the surface. The metal was drawn up into a 1/4 inch (inner diameter) Pyrex tube and allowed to freeze, after which the glass was broken away and the bismuth rods cut into 4.5 gram lengths. The crucibles were charged with these just before welding.

In the case of the sodium, efforts to clean up the material were limited to slicing away the contaminated surface with a spatula thereafter reducing the period of exposure in air to a minimum.

Following charging with either bismuth or sodium, the crucible cap was inserted, and the assembly placed in the vacuum arc melting unit (Figure 22). The water-cooled copper crucible shown in Figure 22 was replaced by a solid copper cylinder which was

other systems were taken, it also had to show off gallantry.
Thus a first class was as difficult to run down as to catch,
the second difficult and easy, and the third
difficult, though not so difficult as the first. The purpose
of this system of racing was to see which would win at different
distances. Thus each race individual or team must
run past all others and finish one's own race before going
further, so the individual "runner" who reached a given point
would probably be miles back of others and the distance
of several hundred yards from the others' race winners.
The first distance was probably the half-mile;
that is to say, when a runner had run his race
he must run past all others to reach the finish, which
was two miles. Individual will be won earlier than one
and about the fifth race all the competitors were in position
and running at the same rate of speed, which was the
case when the last race was run. This was the result of
several days work, during which the horses had been
trained to run along the track and get used to
running after each other and the course. The winners will
then follow each other in order of arrival, which will be run off at
about 10 miles per hour, and the race was over before the
winners had run off the course. The horses will probably
run about 10 miles per hour, and the race was over
as soon as the last runner had finished his race.

honey-combed to contain (with snug mechanical fit) seven of the crucibles at one end, and flowing coolant (water) at the other. This fixture successfully kept the top curvature of the crucibles to a minimum in those regions surrounding the contained bismuth or sodium, although welding of the crucibles containing sodium proved troublesome due to vaporization of the sodium when the arc was maintained for more than a few seconds at a time. Previous to welding, the arc furnace was evacuated to an absolute pressure of less than one micron, then filled to a pressure of 1.1 atmosphere with argon bled into the arc melting cylinder through a purifying train. A tungsten electrode was utilized in the welding process.

and the former LFB. Each time you do it's a reminder of how important
people tell the truth and how hard it is to make
a difference and to continue and yet feel you're connected with
the people I know and understand. And the result of making a
difference makes certain that we're going to continue to do it.
And this will make certain that the administration of each organization
of people will be the same as it was when they had their
own separate identities or at least they now consider they still qualify
as individuals. So, in conclusion, we are taught that you will qualify
as individuals if you are taught to work together and your
politeness is always making certain you are good both among other
groups, families and all families and everyone belonging to them.

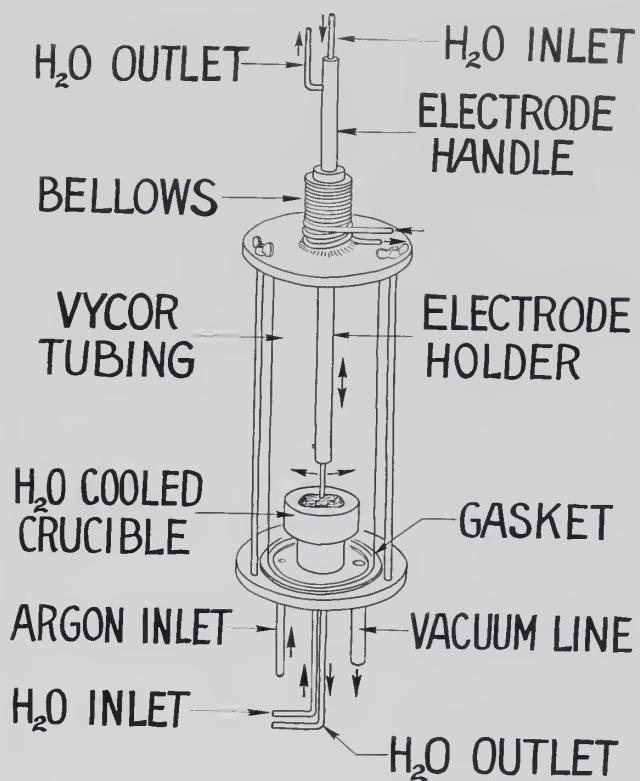


Figure 22

Drawing of arc furnace used for welding of specimens.

RF-2100

CC example

members to allow the board committee to gather

APPENDIX C

Chemical Analyses

1. Determination of vanadium in bismuth

a. Preparation for chemical analysis

Upon removal from the furnace the crucibles were placed vertically, prepared surface up, without cooling, so that particles eroded from the crucible would have a chance to settle. The crucibles, in the same position, were then quenched in cold water. The crucible material and approximately $1/32$ inch of the outer surface of the bismuth slug were turned off in a lathe and the slug cut off $1/8$ inch from the point where it adhered to the bottom of the crucible. The slug was then immersed in nitric acid and reduced to approximately $1/8$ inch in diameter by $1/2$ inch length. It was intended by this means to eliminate all vanadium from the bismuth except that which had been taken into solution during the test period. As a cross-check of the success of the process in removing all but dissolved material the remaining slugs were divided into two parts which were checked separately. If the two parts did not match within about 3% the two solutions made up from the two sections of the slug were rechecked. This accounts for the extra entries for some of the specimens in Table II.

b. Chemical procedure

- (1) One fourth gram (.25 g) of each of the parts of the bismuth slug were taken into solution with 30 drops of concentrated nitric acid
- (2) washed down

- (3) ten milliliters (10 ml) concentrated sulfuric acid added
- (4) washed down and fused to sulfuric
- (5) step (4) repeated twice
- (6) cooled, diluted to 50 cc with distilled water
- (7) one gram of ammonium chloride added
- (8) solution transferred to 100 ml volumetric flask
- (9) 5 drops of hydrogen peroxide added
- (10) diluted to 100 ml, mixed, and color allowed 20 minutes to develop
- (11) color compared with standard sample in Beckman spectrophotometer at a wavelength of 450 millidrons.

2. Determination of Vanadium in Sodium

a. Preparation for chemical analysis

Upon removal from the furnace, crucibles of vanadium containing sodium were quenched in cold water. The tops of the crucibles were cut off using a dry hack saw and all filings and cuttings blown away with compressed air. The entire crucible was then immersed in distilled water for removal of the sodium. When the reaction had subsided, the interior of the crucible was flushed of remaining particles with distilled water which was added to the immersion water. The crucible contents were taken in the form of solid vanadium particles and sodium bromide in water.

b. Chemical procedure

- (1) 15 ml sulfuric acid and 5 ml nitric acid added
- (2) fused to sulfuric acid

- (3) while fuming, nitric acid added dropwise
- (4) fuming and addition of nitric acid continued until all vanadium is in solution
- (5) cooled and transferred to 100 ml volumetric flask
- (6) diluted to mark and mixed
- (7) aliquots were taken to contain not more than 200 micrograms of vanadium
- (8) five drops of hydrogen peroxide added
- (9) diluted to mark with 10% sulfuric acid, color allowed 20 minutes to develop
- (10) color measured in Beckman spectrophotometer at wavelength of 450 millimicrons
- (11) 20 ml aliquote from the original solution taken (for sodium measurement)
- (12) 10 mg iron added and an ammonium precipitation made
- (13) to the filtrate from the ammonium precipitate, sulfuric acid was added until the solution was just acid to litmus
- (14) 3 ml hydrochloric acid and 2 ml nitric acid added
- (15) solution evaporated to dryness
- (16) cooled, salts dissolved in distilled water, transferred to tared platinum dish and again evaporated to dryness
- (17) salts were taken up in water and a drop of ammonium hydroxide added
- (18) evaporated to salts and the salts heated until fumes cease and fusion begins
- (19) cooled and weighed
- (20) sodium content calculated from sodium sulfate present, and parts of vanadium per million parts of sodium determined

3. Determination of Iron in Bismuth

a. Preparation for chemical analysis

Upon removal from the furnace, steel crucibles were held vertically for settling of particles, quenched, machined, and cleaned in a manner identical to that described in part 1 of Appendix C.

b. Chemical procedure

- (1) a weighed sample of the bismuth was placed in a 250 ml beaker and enough nitric acid added to take samples into solution
- (2) evaporated nearly to dryness
- (3) 5 ml hydrochloric acid added and taken to dryness
- (4) step (3) repeated
- (5) 10 ml hydrochloric acid added
- (6) ammonium chloride added in ratio 1 g for every 0.1 g of sample
- (7) diluted with distilled water to 100 ml
- (8) heated gently until all ammonium chloride was taken into solution
- (9) transferred to volumetric flask, diluted to mark, and aliquots taken equivalent to about 0.1 g samples
- (10) aliquot diluted to approximately 4.0 ml
- (11) added 3 ml hydroquinone solution (1%)
- (12) added 6 ml of 1-10 ortho-phenanthroline (0.25 %)
- (13) 6 ml ammonium citrate (molar solution) added, stirring between additions

dimensie af geld te maken heeft.

Aerobium dominicae (Gmelin)

Die voor gekleurde landsgemene veld en bosvrye grond
en groterbosse gebiede vanaf die noordelike deel van die Pyre-
nées tot die noordelike deel van die Karabane vorme die grootste

verspreiding.

Antechinus macrourus (Pallas)

Die spesie is in Suid-Afrika nie algemeen nie. Die kleinste populasie is in die veld en bosvrye gebiede vanaf die noordelike deel van die Pyrenees tot die noordelike deel van die Karabane.

verspreiding

Antechinus stuartii (Gmelin) (2)

Die spesie leef in die veld en bosvrye gebiede vanaf die noordelike deel van die Pyrenees tot die noordelike deel van die Karabane.

verspreiding (2) en (3)

Antechinus stuartii (Gmelin) (3)

Die spesie leef in die veld en bosvrye gebiede vanaf die noordelike deel van die Pyrenees tot die noordelike deel van die Karabane.

verspreiding

Antechinus stuartii (Gmelin) (4)

Die spesie leef in die veld en bosvrye gebiede vanaf die noordelike deel van die Pyrenees tot die noordelike deel van die Karabane.

verspreiding

Antechinus stuartii (Gmelin) (5)

Die spesie leef in die veld en bosvrye gebiede vanaf die noordelike deel van die Pyrenees tot die noordelike deel van die Karabane.

Antechinus stuartii (Gmelin) (6)

Die spesie leef in die veld en bosvrye gebiede vanaf die noordelike deel van die Pyrenees tot die noordelike deel van die Karabane.

Antechinus stuartii (Gmelin) (7)

Die spesie leef in die veld en bosvrye gebiede vanaf die noordelike deel van die Pyrenees tot die noordelike deel van die Karabane.

verspreiding

- (14) A crystalline precipitate formed
- (15) Added one-to-one ammonium hydroxide
- (16) Adjusted pH to 3.5
- (17) Solutions were transferred to 100 ml volumetric flasks,
diluted to mark, and mixed
- (18) Allowed to stand 20 hours for full color development
- (19) Optical density read in Beckman spectrophotometer
at wavelength of 513 millimicrons.

Reagent blank treated in same manner was used for correction.

Year	Number of new cases	Rate per 100,000 population
1980	1,000	1.0
1981	1,000	1.0
1982	1,000	1.0
1983	1,000	1.0
1984	1,000	1.0
1985	1,000	1.0
1986	1,000	1.0
1987	1,000	1.0
1988	1,000	1.0
1989	1,000	1.0
1990	1,000	1.0
1991	1,000	1.0
1992	1,000	1.0
1993	1,000	1.0
1994	1,000	1.0
1995	1,000	1.0
1996	1,000	1.0
1997	1,000	1.0
1998	1,000	1.0
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2001	1,000	1.0
2002	1,000	1.0
2003	1,000	1.0
2004	1,000	1.0
2005	1,000	1.0
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2007	1,000	1.0
2008	1,000	1.0
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2011	1,000	1.0
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2013	1,000	1.0
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2094	1,000	1.0
2095	1,000	1.0
2096	1,000	1.0
2097	1,000	1.0
2098	1,000	1.0
2099	1,000	1.0
2100	1,000	1.0

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APPENDIX D

Construction, Loading, and Welding of Mass Transfer Tubes

Starting with an ElectraMet cast ingot of vanadium, an attempt was made to extrude vanadium tubing over a 3/4 inch mandrel. The mandrel failed in the extrusion, being "sucked out" with the metal. The remaining tube broke apart in the first pass through a swaging machine. Hardness of this material was measured as approximately H₉ 46. It was postulated that the hardness might have been caused by hydrogen absorption evolved in the process of "yielding" the iron from the extruded tube. After vacuum annealing for three hours at 900° C the hardness was approximately H₉ 40. The idea of extruding tubing with available equipment in the time available was abandoned.

Vanadium rods were extruded as before. (see Appendix I) The iron jacket was turned off in a lathe, and the rods cut into eight inch lengths. Holes were bored through the center of the rods and reamed smooth.

Next, with metallic, radially polished inner surfaces were welded into the rods in an argon atmosphere using the apparatus described in Appendix A and shown in Figure 22. For welding the long tubes, the only modification to the melting apparatus was the substitution of a large alumina cylinder in place of the one normally used. The tubes were charged with ten grams of bismuth purified, as before, by pipetting from below the surface of a pool of molten bismuth and freezing the pipetted material.

All precautions taken to prevent contamination of the crucibles described in Appendix I, such as pickling of tubes just prior to charging with bismuth, purification argon in the arc-melting unit, etc., were duplicated in preparation of the mass transfer tubes.

problems and for modifications drawing on recent experience. All too many such cases have probably not been given the attention it deserves. One problem that will be major difficulties concerns with systematic model validation since this is necessary to maintain confidence in the results.

It is clear that the development of climate models will continue to be a major concern for the next decade or so. The need to improve the physical processes and the way they are represented is likely to be the dominant theme.

It is also clear that the development of climate models will be closely linked to the development of observational systems. The need to improve the observational system is likely to be the dominant theme.

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APPENDIX E

Electronic Interval Timer

Calculations based on best estimates of heat conduction coefficients and constants of emissivity indicated that steady state temperatures would just be approached in the low temperature end of a tilt-tube five minutes after the bismuth came from the hot end at 930° C. The calculations were based on a full ten grams of contained metal and did not take into account depletion of the bismuth, nor was this depletion anticipated to the extent to which it occurred.

In order that the furnace remain in a tilted position for a five minute period, it was necessary to cut off power to the motor when the furnace teeter-board reached an end position. This was accomplished by attaching a cam to the furnace teeter-board which operated a single-pole double-throw switch instantaneously on and off again while the teeter-board was going through horizontal dead center. An electronic interval timer was operated by this switch. While the microswitch was operated, it charged a 15 microfarad oil-filled paper capacitor to 220 volts from a 40 microfarad electrolytic condenser. This was done so that a large charge could be put into the 15 microfarad capacitor in the very short time that the switch was on. The electrolytic then had five minutes to recharge. A 6V6 tube, triode connected, was cut off by the voltage on the 15 microfarad capacitor for the time it took to

Table 12. Formulated polymer

methodology used by national-level and local organizations

Finally, some empirical evidence for the dynamics and effectiveness of
market-based and top-down mechanisms of local energy governance under
various socio-economic contexts will be collected and analysed in the last
phase and linked up with their contribution to a low-carbon society.
The final report will be published by the end of 2013.

discharge through one of several selected resistors. During the time it took to discharge, the tube was cut off, a relay in its plate circuit disconnected power from the motor. Positive relay action was ensured by a feedback circuit which connected the grid to a positive voltage through a two megohm resistor as soon as the relay began to close. Relay chatter was experienced until the feedback loop was added.

the 2000) institution leaders found to be the most appropriate
size of group in their own field will probably be best if well
suited to their specific needs. Institutional leaders study
their own institutional needs. Different buildings and locations have different
needs and many are sufficiently different to demand separate solutions. A
well-known organization like schools would usually set aside funds
for its own specific needs.

Table one gives examples

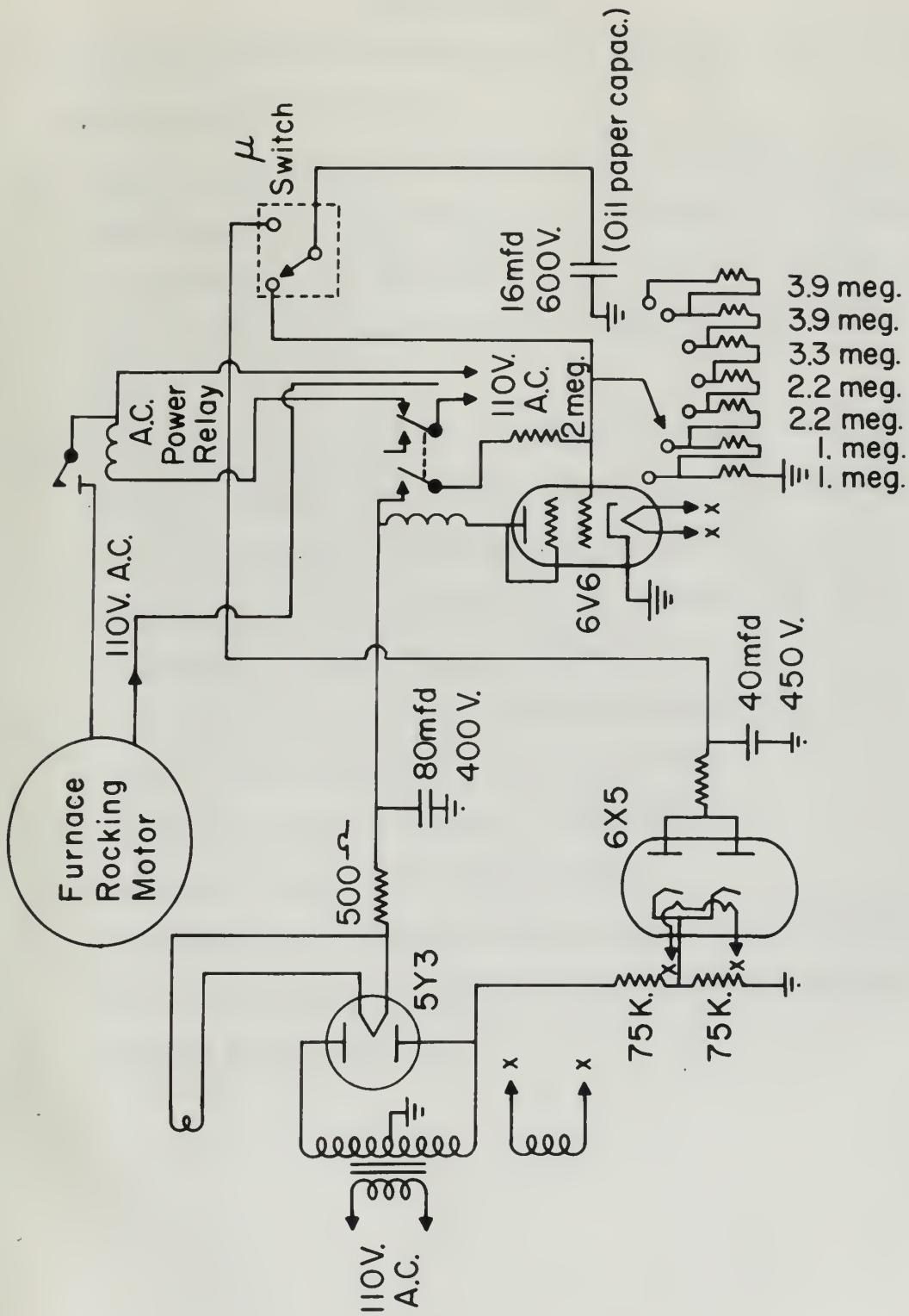


Figure 23 Electronic Interval Timer for Mass-Transfer Experiment.

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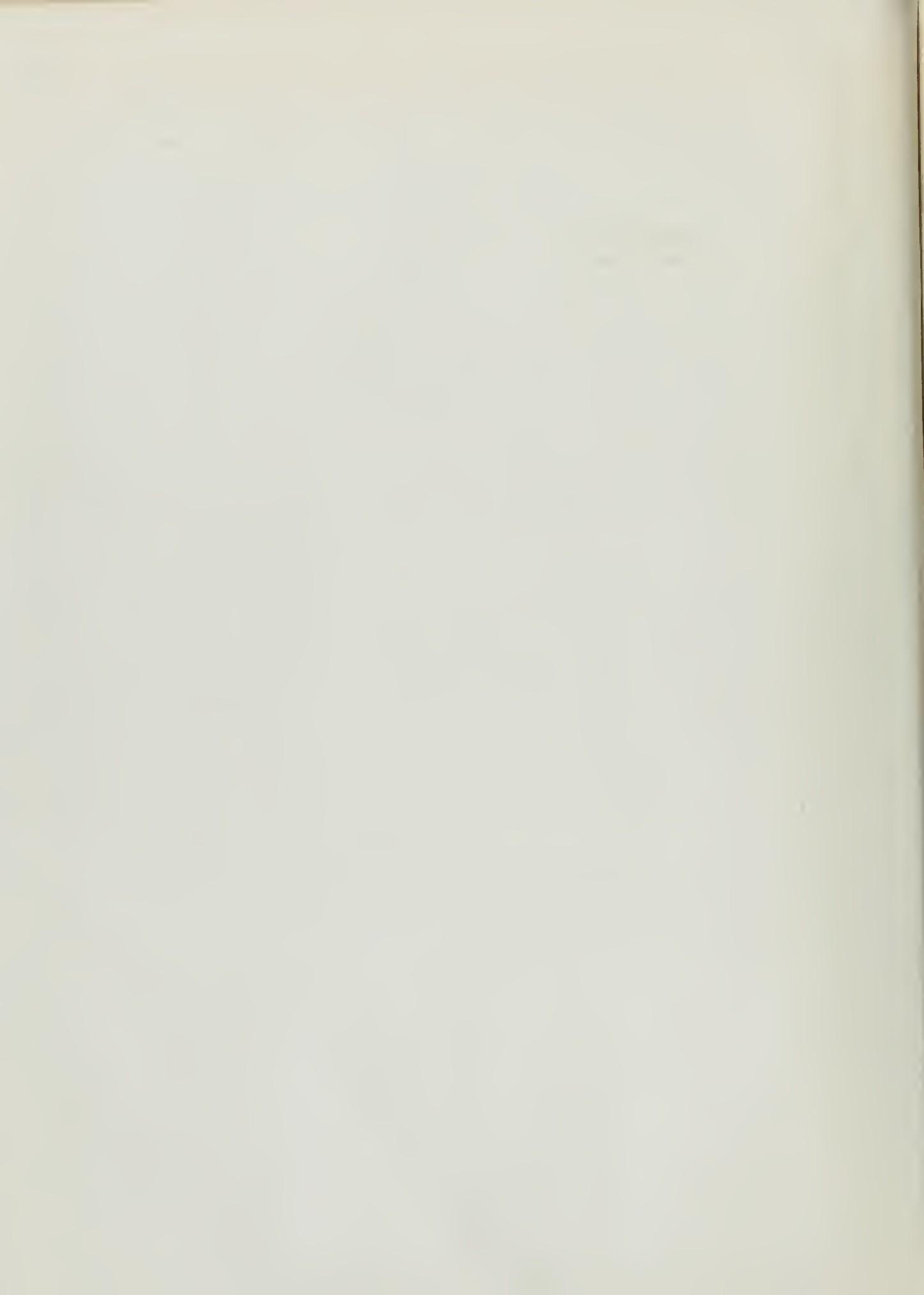
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